SURGICAL TREATMENT

BANCROFT AND MURRAY

MOTOR-SKELETAL SYSTEM

PART TWO

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SURGICAL TREATMENT OF THE MOTOR-SKELETAL SYSTEM

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PART TWO

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Supervising Editor's Note

Some time ago when this work was still definitely in the prenatal stage, the editor made a careful and exhaustive survey of all the available books dealing with the broad subject of surgical treatment. This survey showed clearly that, while there was no lack of books, there was none filling a certain need. The foregoing statement should not be taken as implying that the existing works on surgery are without merit. Many of the works on operative surgery list a large number of operations, although many of these operations are now obsolete or at least obsolescent, and are of historical rather than of current clinical interest. Also, in many instances, the reader is not fully informed concerning the difficulties, disadvantages, and contraindications for the various procedures, the discussion being limited to the operation itself.

The editor determined, therefore, that the present was an opportune time to produce an entirely new work on surgical treatment. It seemed advisable to establish a pattern of treatment and coverage for each field which would safeguard against omissions and would present the up-to-date, authoritative material in the most concise and usable form. This pattern would include not only the operation itself, but also indications for it, a full discussion of the preoperative preparation of the patient, the common sequelae, a full presentation of the prognosis, and a complete discussion of the most approved postoperative treatment. In this connection it was recognized by the editor, the associate editor, and the individual contributing authors, that because of the special problems in presenting some fields, this pattern should not be a straitjacket but that some concessions and commonsense adjustments would have to be made.

Since this is primarily a work on surgical treatment, no attempt has been made, in general, to present the diagnostic problems or the etiology. However, these subjects have been taken up when it seemed necessary in order to assure attainment of the over-all picture which it is the purpose of the book to present.

The bibliographic references have been carefully selected to cover only the most important material rather than to accumulate a long list which, while they may bear testimony to the erudition and diligence of the author, would be of little value to the reader.

Frederic W. Bancroft

Preface

Disregarding the outmoded and illogical attempts which are still made to define strictly the mutual limits of orthopedic surgery and general surgery, these volumes purpose to present the surgical treatment of all conditions involving a physiologic unit—the motor skeletal system. The system is comprised of the skeleton and those structures which provide for its support and motor activity—the bones, the joints which articulate them, the muscles, tendons, fasciae and ligaments which motorize and stabilize the joints, and the bursae associated with those structures. Neurologic structures as such do not belong in this system, but the results of neurologic lesions may require operation or other surgical treatment applied directly to the motor skeletal structures affected. Only such results of neurologic lesions are dealt with. On physiologic grounds there are therefore included all conditions which involve the skeleton and the structures directly concerned in its support and motorization, whether the disturbing lesion be trauma, disease, tumor, or deformity. On the same basis, lesions of the extremities or trunk not directly involving the functioning of the motor skeletal system have been excluded.

The title, Surgical Treatment, implies that all procedures, operative as well as nonoperative, utilized in the care of the individual conditions are included in the text. All discussion of the general features of operating room technic, pre- and postoperative care of the patient as a whole, chemotherapy, and similar phases of general surgical care are omitted. Any variation from ordinary surgical technic called for in the surgery of the motor skeletal system will be specifically cited.

These are not designed as reference volumes. They are designed for the use of the average general surgeon and orthopedic surgeon over the country at large who has to deal with lesions involving the motor skeletal system. The material has been presented from the standpoint of indicating what to do, when to do it, how to do it, and what not to do for the various conditions affecting this system. The subject matter is grouped, insofar as is possible, according to the type of disturbance involved, and the individual contributors have been given great latitude in the expression of their personal opinions and preferences. At the same time, the attempt has been made to include all of the more commonly used and justified procedures. This naturally leads, in some instances, to seemingly contradictory opinions by the various contributors on treatment rationale or procedure in various regions of the body. Where these apparent contradictions are not adequately discussed in the text, the reader will find explanatory editorial comment, or will be referred to a section in the second volume (Chapter 22) on general considerations to clarify the situation. This arrangement allows, we believe, the inclusion of all valid viewpoints in the presentation of the subject.

There is some duplication in the description of operative procedures. This has been allowed to stand whenever an individual contributor's description contains a variation or variations in technic and procedure which are a matter of interest or practical importance. Cross reference to such duplication is provided in the text by the editor, who has enclosed his interpolated remarks within brackets.

The illustrations are designed to combine

clarity of presentation and pleasing appearance in that order of importance, and no illustrations have been included unless it was felt that they provide needed clarification of the text

The cheerful and wholehearted cooperation of the contributors to this volume leads, we hope, to a coordinated presentation of the surgical treatment of those conditions which affect a physiologic unit—the motor-skeletal system

Due to the exigencies of wartime conditions, many and varied obstacles to the publication of these volumes have arisen. Through all the difficulties which have been encountered and despite all the delays and adjustments thereby necessitated, the contributors have stood by valiantly, and I should be remiss if I did not take this opportunity to express my heartfelt appreciation of their efforts and forbearance.

The chapter on Military Surgery was originally written just before our entry into World War II. With his usual directness and efficiency, the Surgeon-General of the Army has cooperated to the full in helping to bring that chapter as nearly up to date as the constantly changing conditions of the present conflict make possible—this, despite his many and arduous duties and responsibilities We are duly and appreciatively grateful, and assume full responsibility for any shortcomings which may exist in that chapter.

Because of the fact that many of the authors are in service with the Armed Forces, proof has been read by the editor. He asks the indulgence of the individual writers under the circumstances, and assumes responsibility for any error which may exist.

The publishers, J. B. Lippincott Company, have stepped into a difficult situation, and have exhibited a consideration and cooperativeness which have made it finally possible to issue the publication

I am deeply indebted to my secretary, Miss Clara Barry, for her unremitting and efficient aid in the preparation of the manuscript.

Clay Ray Murray

CONTENTS OF PART TWO

SECTION SEVEN
FRACTURES AND DISLOCATIONS IN GENERAL

SECTION EIGHT
FRACTURES AND DISLOCATIONS OF FACE

SECTION NINE
FRACTURES AND DISLOCATIONS OF TRUNK

SECTION TEN
FRACTURES AND DISLOCATIONS OF UPPER EXTREMITIES

SECTION ELEVEN

FRACTURES AND DISLOCATIONS OF LOWER EXTREMITIES

SECTION TWELVE

SPRAINS, SPRAIN-FRACTURES, MUSCLE AND TENDON INJURIES

SECTION THIRTEEN
BIRTH INJURIES OF MOTOR-SKELETAL SYSTEM

SECTION FOURTEEN
MILITARY SURGERY

SECTION SEVEN

FRACTURES AND DISLOCATIONS IN GENERAL

part of, that treatment General appreciation of this fact will lead to more intelligent consideration of both the patient and his lesion in the treatment of trauma The question is discussed in detail below

Rather than enter here into a long and detailed discussion of the rapid progression of significant events in the tissues following trauma, let us state (1) that the process covers a period of hours not days, (2) that until it has reached its maximum our treatment measures are designed to stop its progress and to minimize its extent, (3) that after it has reached its maximum we have the much more difficult problem of eliminating its results before intelligent treatment of the primary condition can be carried out, and (4) that it is frequently impossible to meet the latter problem more than partially

We may discuss some therapeutic guides on the basis of these factual statements and their implications These therapeutic guides are founded on clinical experience verifying the statements and not on theory based on them It may well be said that many of the points discussed are extremely elementary They are, and advisedly so It is the overlooking of elementary principles, the misinterpretation of them as rigid rules, or their wrongful application which most often leads to doing the wrong thing or the right thing at the wrong time

THERAPEUTIC GUIDES

1 The prompt application of adequate first aid and emergency care is one of the more important factors in minimizing the difficulties of subsequent definitive treatment It is described, therefore, in some detail below

2 It is commonly stated that reduction should be accomplished as soon after injury as possible This statement of a principle is capable of misinterpretation Its meaning could be more clearly expressed by saying that reduction should usually be accomplished, no matter what the method used, before the progressive pathologic changes in the tissues have become complete, whenever possible This covers a variable period of time of from 12 to 24 hours, and is to be interpreted for the individual patient in terms of the amount and character of the swelling and of loss of elasticity in the tissues This factor exerts a great influence in modifying the application of all traction or traction suspension methods, and in the operative reductions These matters are discussed in greater detail below

Reduction before the tissues become tense with swelling and indurated by infiltration with hemorrhage and exudate is easier, more apt to be satisfactory, and is easier to maintain when secured Adequate first aid, particularly if traction is employed, is effective in slowing up the rate of this change and in limiting its extent When the case is seen after the pathologic changes in the tissues are well established, it is often wise and logical to delay reduction until intensive active therapy can restore the soft parts to a relatively normal state, particularly if the fracture site is surrounded by muscle bellies

This does not mean waiting for the swelling to go down it means the employment of such active therapeutic measures as moderate elevation of the part the use of low-degree constant or prolonged heat in any form, the use of massage, the active exercise of such muscles as can be safely used, the substitution for active muscle exercise by the Smart or Bristow coil (discussed below under physical therapy measures), and the employment in cases of extreme soft part tension and infiltration of brachial or paravertebral novocaine block Within 24 or 36 hours of such a regime, many a tense, swollen, and indurated extremity, with congealed and inelastic muscles, can be rendered relatively normal in size and in tissue consistency Reduction measures may then be used with greater ease, with less violence and trauma, and with greater success

At times it is possible to combine the

reduction measures and the treatment directed against the accumulated pathologic state in the tissues—as in the traction-suspension methods described below. This is sometimes a great blessing, as in supracondylar fractures of the humerus with threatened Volkmann's ischemia (see Chapter 31 and also Volkmann's Ischemia below). In some fractures, such as Colles', finger and hand fractures, single malleolar ankle fractures, and vertebral compression fractures, reduction may be carried out at any time, since the influence of the soft-part pathologic state on reduction and maintenance of reduction is negligible.

There is, however, no question but that reduction before the establishment of the pathologic state in the soft tissues is always advantageous, and that the earlier it is done the better.

3. It is commonly stated that the reduction should be as complete and accurate as possible and should be accomplished with as little trauma as possible.

The latter part of this statement is universally true. The attempt should be to "wish" the fragments into place. This requires accurate determination of the displacement present, knowledge of the muscular and mechanical forces to be dealt with, and due consideration for the pathologic condition in the surrounding soft parts and for the anatomic structures lying therein. It calls, moreover, for skillful employment of the mechanical forces available —for the use of force rather than violence, of intelligence rather than brute strength.

A few examples may serve to make these differences clear. In fractures of one or both bones of the forearm in which there is obliquity from above on the volar surface to below on the dorsal surface (Fig. 521 a) with the lower fragment displaced dorsally (the common displacement), it is obvious that straight traction would have to elongate the part considerably beyond normal to allow of pushing forward the dorsally displaced fragment. If the dorsal periosteum is intact, as is frequently the case, this is practically impossible. If the dorsal periosteum is torn it may be possible if the muscles are not too infiltrated, but only at the expense of badly overstretching muscles, or of tearing individual fibers, to gain length. Shifting of the distal fragment to one side or the other of the proximal one,

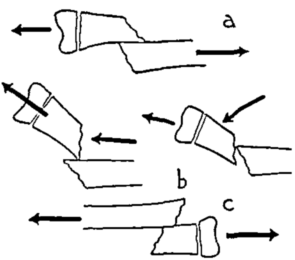


FIG. 521. Reduction by "toggling." (a) Fracture of lower radius with obliquity unfavorable for reduction by traction and countertraction forces (arrows). Reduction would necessitate extension beyond normal length of bone. (b) "Toggling," accomplished by dorsiflexion of distal fragment during traction in direction of arrow and pressure distalward by thumb of other hand in direction of arrow. Once the ends of the two long surfaces are slid by one another, traction and push can be changed to easily complete reduction, as shown by arrows. (c) Fracture with obliquity allowing of easy reduction by mere traction and countertraction.

so as to be able to slide them together medially or laterally, is often rendered impossible by the structures attached to the bones (interosseous membrane and muscles).

A simple procedure embodying the well-known principle of toggling solves all these difficulties with a minimum of trauma. It is illustrated in Fig. 521 b This same procedure would obviously also be called for

in fractures in the same location in which marked serration of the fragment ends existed It is, of course, applicable under similar conditions in many other regions

When the fracture, however, shows an obliquity from below and volarly upward and dorsally (Fig 521 c), traction merely enough to gain normal length plus moderate direct forward pressure on the distal or dorsal fragment is completely adequate unless there is coincident interposition of tissue evidenced by absence of bony crepitus during attempted reduction

Any critical analysis of the situation would preclude the attempt at violent manipulations in straight traction in the first two types described, and would lead to the adoption of the mechanically adequate and least traumatizing procedure as the initial one Yet this is very frequently used, if at all, only after the straight traction and manipulation have failed, and have, incidentally resulted in additional trauma comparable to that of the original injury

Fracture of the neck of the femur is another example of the point at issue The essential forces employed in the reduction of this fracture by closed methods are internal rotation and abduction of the shaft and the amount of force is evidenced by the degree of each obtained, not by the violence with which each is carried out Very little traction is needed Moreover if end to side position is present some form of preliminary lateral traction is essential (see Chapter 35) In the latter instance no closed reduction can be accomplished without lateral traction Internal rotation should be carried to but little beyond normal limits, and abduction to the limits beyond normal which will indicate that a coxa valga position of the desired degree has been obtained These procedures can be carried out slowly with very little violence There really should be nothing shocking about the closed reduction of a fracture of the neck of the femur

The common statement that the reduction should be as complete and accurate as possible is true as a generality but requires intelligent interpretation in the individual case

In the lower extremity, because of the functional importance of weight bearing lines and strains on it and on the superimposed torso, the statement becomes nearly universally true

In apophyseal fractures, on the other hand, it is frequently not true There is a great deal of unnecessary and uncalled for trouble and disability time wasted on regard for meticulous replacements of humeral greater tuberosities, humeral internal epicondyles, femoral lesser and greater trochanters, vertebral transverse processes, iliac spines etc *These become important only when the degree and type of displacement are known to result in impairment of the function of the muscles attaching to them or in interference with the function of an adjacent joint*

In the upper extremity, impacted fractures of the surgical neck of the humerus in even marked adduction deformity in the elderly and fractures of the anatomic neck with gross displacement (Chapter 29), Colles' with moderate deformity in the aged or in the arthritic (Chapter 32), adult radial head fractures with displacement (Chapter 31), and humeral shaft fractures (Chapter 30) offer frequent exceptions to the application of the general principle of accurate and careful reduction In general, nevertheless, the principle holds true

In fractures in children it is known that the inherent growth powers will correct residual deformity to a really remarkable degree This power is most marked in the infant and diminishes steadily up to the time of epiphyseal closure, when it ceases to function The viewpoint has been taken by some that no attempt at accurate reduction need be made in a child In general, such a viewpoint is in error In fractures of the newborn it is valid, since the difficulty

of maintaining the reduction is frequently an insurmountable obstacle (Chapter 43).

In the older infants and young children as accurate a reduction as possible should be attained short of radical procedures such as skeletal traction or open reduction. The inherent growth factor in the child should be given as little as possible to correct—it should constitute a hope to make up for our deficiencies, not a substitute for our efforts. The author agrees thoroughly with the remarks made by Walter E. Lee in Chapter 36 in reference to this matter in fractures of the femur in children.

In fractures of the radius in children, even of the greenstick variety, an angular deformity is very slow to correct if the angulation is against the normal curve of the radius, and in older children may not correct at all. The persistence of this reversed radial curve leads to a loss in rotation in a surprising number of cases, even though the reverse angulation be moderate. When the angulation is in the normal curve of the bone, on the other hand, the correction in younger children is rapid, and the interference with rotation does not manifest itself even when some deformity persists (Fig. 522). It is unfortunate that the viewpoint that correction is unnecessary in children has been applied rather generally in supracondylar fractures of the humerus. Correction of the anteroposterior displacement is essential in those cases with vascular embarrassment, and uncorrected lateral tilts and rotations are responsible for many of the changed carrying angles which are so frequently seen in adequate follow-ups on these cases. A changed carrying angle is like a reverse curve in a radius in that it is slow to correct and apt to persist. It is true that functional activity is not impaired by the change in angle, with the exception, perhaps, of a certain number of slow and gradual ulnar palsies in cases with increased carrying angle. But the appearance is unsightly, and is particularly annoying in a girl (see Chapter 31).

In children in their later teens there should be no difference in viewpoint from that held for adults as regards correction of displacements. Their powers for correction by that time have become slight and the time left during which it can be exercised is too short to have any practical value.

A word regarding correction in epiphyseal separations. The amount of displacement is no criterion as to the possibility of subsequent growth disturbance. Complete growth stoppage is seen in cases in which little or

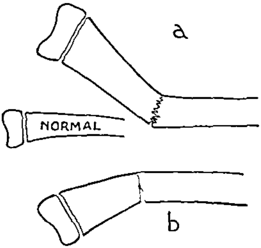


FIG. 522. Fracture of radius with angular deformity. in (a) in a direction reversing normal curve of radius in a lateral view, and in (b) in a direction increasing normal curve.

no actual displacement can be demonstrated, and cases with complete displacement may show no growth disturbance whatever. Aitken of Boston published the analysis of a series of 100 cases in which it seemed to be evident that the existence of a fracture line in the epiphysis itself, into or crossing the epiphyseal line, predicated subsequent growth disturbance.

In an analysis of some 1200 cases with a five-year or longer follow-up on the Fracture Service of the Presbyterian Hospital in New York City, the author and his associates have been unable to verify this find-

ing or to establish any criterion for prognosis as to later growth disturbance except that the proportion of faulty growth or growth stoppage cases seems in general to increase directly with the size of the bone involved and that the disturbance may not become evident by x ray comparison or careful clinical check for from one to three years after injury The percentage of cases

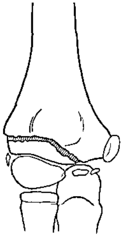


FIG 523 X ray tracing of low supracondylar fracture of humerus entering ep physeal line Such a fracture may injure ep physeal plate for internal condyle and result in growth disturbance w th a reverse carrying angle

showing disturbance runs from 4 per cent clinical and 8 per cent x ray in the lower radial epiphysis to practically 50 per cent in the lower femoral epiphysis The assumption is that the growth derangement depends upon the damage done to the differentiating portion of the epiphyseal cartilage

In the earlier years the correction of the deformity occasioned by the displacement itself is fairly rapid over a period of a few years if there has been no appreciable damage to this portion of the epiphyseal cartilage For that reason it is unwise in general to make repeated and forceful attempts to reduce an epiphyseal displacement and operative reduction is extremely apt to result in growth disturbance The attempt to secure as good a reduction as possible with the use of moderate force should certainly be made but the use of violence or of repeated attempts to make the reduction perfect or near perfect is to be deplored

Operative reduction should be reserved for those cases in which practically complete displacement persists despite the use of moderate force by closed manipulation When operative reduction is done the utmost gentleness should be used particularly in handling the surrounding soft parts and the face of the epiphyseal ends should not be traumatized by instruments If the epiphysis is near the time of closure open reduction to secure satisfactory position is not contraindicated

An exception to the general rule in these cases is the upper femoral epiphysis Because of the special problems involved in this region meticulous correction of displacement and even deliberate stoppage of growth may be indicated (Chapter 35)

In every case of epiphvseal separation whether or not there has been material displacement *the parents should be warned of* the possibility of subsequent growth disturbance and urged to keep the child under observation for the next three years at six month intervals so that the disturbance if it occurs can be picked up early and an appropriate course of action planned

In low supracondylar humeral fractures in the younger children the possibility of subsequent growth disturbance with resultant change in the carrying angle must be kept in mind The lower end of the bone is largely cartilaginous and the fracture line frequently passes through it on one side or the other although not visible by x ray (Fig 523) This is in effect a potential epiphyseal growth disturbance and should be regarded as such

4 It can be accepted as a general principle that postreduction immobilization should be as inextensive as possible consistent with adequate fixation of the frac

ture fragments, and should be continued for as short a time as possible. No matter what the method used, it should be used to carry out this general principle to the maximum degree which the limitations of the method will allow. This point is covered below in some detail in the discussion of the various methods of immobilization.

In this connection a word might be said about the common habit of gauging the time necessary for immobilization by the appearance of callus visible by x-ray. This practice frequently leads to unduly prolonged immobilization. In the upper extremity the limited or full exercise of active motion without weight-lifting or heavy exertion is often possible before x-ray shows any definitive calcified callus, and in the lower extremity active motion without actual weight-bearing is often similarly possible, and weight-bearing with brace or walking-plaster support permissible and advisable. The criteria for judgment in both bones of the forearm, the humerus, the femur, and the leg bones for the resumption of such partial or restricted activity are clinical. They consist of palpable callus mass, absence of motion in any plane on careful clinical test, and absence of indirect tenderness at the fracture site on manipulation of the extremity.

The author does not intend in any way to decry the use of x-ray check in the treatment of fractures. Blind and childlike faith in x-ray as the sole criterion, however, particularly when the pictures are taken through plaster as is frequently the case, is, he believes, a mistake resulting in undue prolonging of convalescence. It must be remembered that x-ray does not record the mere presence of calcium in the tissues. It records it only when it has reached a sufficient concentration to be made visible by the x-ray technic employed. Long before this time, palpable callus with sufficient calcification to allow of various degrees of function may be demonstrated by the clinical criteria noted. In the x-ray examination of metals for flaws, the material can be made to appear flawless by pictures taken with inadequate intensity of exposure. In a reverse manner pictures made by an intensity of x-ray sufficient to show bone detail will not record the diffuse but lightly concentrated calcium content of early callus. There may not even be enough calcium concentration to record by "soft" x-ray, and yet partial function may be safe. One has only to examine gross specimens of healing fractures in the earlier weeks, to feel the gritting sensation in cutting through the tissue, and to see the indisputable microscopic evidence of actual bone formation in the absence of x-ray evidence of "callus" to be certain of this fact.

As a criterion for the resumption of full and unrestricted activity the x-ray is a much more reliable test, if one keeps in mind the fact that visible and external callus is not the whole story. It certainly is common not to see any external callus in intracapsular fractures of the femoral neck, in carpal navicular fractures, in many ankle malleolar fractures, and in many long bone fractures which have had early hairline reductions with rigid internal fixation. The criterion for resumption of full and unrestricted function in these cases is the clouding over or disappearance of the fracture line and the presence of trabecular structure crossing it.

If the x-ray reveals visible external callus at an early stage, so much the better, but in that stage the author cannot help but believe that the value of clinical criteria for the determination of union sufficient to allow of beginning resumption of function is rather generally overlooked and neglected to the detriment of the patient. Simple malleolar fractures without disruption of the ligaments of the inferior tibiofibular joint or other complicating fractures are frequently kept immobilized for six, eight or more weeks because of insufficient x-ray evidence of bony union. It may be necessary to prevent full or unprotected weight

bearing for that length of time in some of these fractures but it is a rare one which requires immobilization for such a period

5 The maintenance during the treatment of the bone lesion of as much functional activity of the part as is possible within the limits imposed by the individual in volved the pathologic situation and the treatment methods available is an impor tant aspect of fracture treatment Progres sive increase in this functional activity within the limits imposed by the bone healing process in the individual location is a corollary The time taken to secure a complete return of functional activity is as important a consideration in planning treat ment as is the end result obtained This is particularly and strikingly true in industry where it is of economic importance

During the period of treatment of the bone lesion functional activity may be par tially substituted for or augmented by the use of physical therapy measures After the bone has healed physical therapy may be used to render progressive functional ac tivity easier and less distressing or bother some to the patient Under no considera tion however must rehabilitation be viewed as a pure physical therapy problem The question of the role of physical therapy in fracture treatment is discussed in detail below

The problem of functional activity should be considered primarily from the standpoint of muscle tendon nerve and vascular func tion *Except under unusual conditions* joints become stiffened by ligaments which are rendered thickened and rigid by the edema and sclerosis occasioned by minute circulatory stagnation and tendons become fixed by virtue of the same effects on meso tenon and paratenon The essential factor involved in the prevention of such circula tory stagnation is coordinated nerve muscle physiology This means that joint move ment ordinarily owes its greatest value to the fact that it represents the exercise of that physiology

This should emphasize the point that *even with joints completely immobilized* very effective functional activity can be secured by the systematic use of voluntary exercise of the muscles which ordinarily activate the immobilized joint The so called walking plaster is an excellent ex ample of this Stiffness of the ankle joint after its use *if the patient walks enough* is not common The plaster should be ap plied with the idea that the patient has to progressively exercise the function of walking without moving his ankle joint not with the idea that he is capable of walking if he so desires

The rationale is to enforce systematic use of the muscles activating the joint and thereby to affect the vitally important mi nute circulation Many of the critics of the walking plaster who have found it ineffec tive insofar as preventing ankle joint stiff ness is concerned have failed to appreciate this basic fact Under such circumstances the method represents an applied waste of time and of effort

Moreover the adequate functioning of the minute circulation (the tissue spaces the lymphatics and the ultimate capil laries) plays a vital role in the successful and early formation of adequate healing tissue or callus and in its prompt and pro gressive calcification All other factors being equal the speed and degree of callus forma tion and its ossification vary directly with the efficiency of the local minute circula tion *Here again physical therapy may be* of help but can never be a complete substi tute for normal voluntary muscle function Occupational therapy so called if intelli gently used can be of great value in helping re establish normal coordination and timing of muscle action

One of the biggest handicaps which exists in the getting back to work of industrial cases is the general lack of interest in, or facilities for the providing of light work as an intermediary stage between disability and full work This situation costs industry

millions of dollars every year. The problem is largely a psychologic one.

A number of self-insured organizations realize the value of restoring a man to the payroll as soon as he is able to do any work, but in many instances he must be able to do his full work before he can be re-employed, or the problem of finding light work is made his responsibility. The light work pays little or nothing more than he has been receiving as compensation during disability, even if he finds it, and it is not too surprising that he is not particularly anxious to find it under the circumstances.

The insurance company will pay him while he is unable to do his work; his employer expects full work for full pay if he takes him on again. He is injured while acting as a rigger or a steel worker, and after six months of disability during which the hardest work he has done has been to push the pedals of a bicycle saw, to work a loom, or to do some light carpentering, he is notified that he is fully capable of returning to his full work as rigger or steel worker. Physically this may be true, but psychologically it is all wrong. Moreover, it is dangerous to allow a man at or approaching the age of 50 to acquire the habit of receiving compensation during idleness for any prolonged period of time, particularly if he has performed hard or arduous work. It is apt to be entirely too pleasant a change from an existence of toil, and the fact must be recognized that a large percentage of individuals at or above the age cited will prefer a subsistence income and idleness to a good income and hard work. It is very easy for such an individual to persuade himself that he is unable to resume work, particularly if the first day results in the development of a number of kinks and aches and sore spots.

Some solution of the light-work problem would do a great deal to cut down disability time in industry. While the physician is properly concerned with the problem it is only partially in his hands.

REDUCTION AND IMMOBILIZATION OF FRACTURES

There are only three basic means of reducing fractures, and three basic means of maintaining and immobilizing the reduction when obtained. Those utilized in reduction are (1) manipulation, (2) traction-suspension, and (3) open reduction. Those designed to hold the reduction and to immobilize the fragments are (1) external fixation, (2) traction-suspension, and (3) internal fixation.

The almost innumerable methods described for reducing and fixing fractures are merely variations of, or combinations of, these basic means For example, the various methods of reduction utilizing pins in each fragment manipulated by a mechanical apparatus, with maintenance of reduction and immobilization by some form of external fixation applied to the pins, differ basically in no way from the combination of manual manipulation for reduction and plaster immobilization for fixation. The former combination, properly applied, is frequently mechanically more effective in securing better reduction with less trauma at the fracture site, mechanically more effective in maintaining the reduction and immobilization of the fragments, and will often allow with safety more functional activity of the extremity as a whole than will the latter during the period of fracture healing.

The purpose of each method, however, is to carry out to the limit of its potentialities the principles of treatment as outlined in the preceding pages. Actually it is quite obvious that a fluoroscopically perfect reduction can well be secured through the great mechanical force exerted by pins and a mechanical apparatus in an extremity in which the muscles are so infiltrated, shortened, and inelastic that a manual manipulation would fail. This great mechanical force can be exerted, moreover, without any great outward evidence of violence to the tissues.

The setscrews, worms, or turnbuckles manipulate easily, but the fact that their effects on the soft tissues are inexorable may be unappreciated or ignored The conditions created in the soft tissues by such an unintelligent application of a sound basic means of reduction can, and often do, more than offset the value of the accurate reduction secured The force employed and the violence inflicted during an attempted manual manipulation in the same case would be strikingly evident, and much more apt to be fully appreciated

This does not constitute a criticism of mechanical means for fracture reduction, it merely emphasizes the point that no matter what variant of any of the three basic means of reduction is used it must be used so as to carry out principles—not in violation of them The same observation is pertinent to the methods used for immobilization of the reduced fracture

Although a wide variety of seemingly strikingly different musical compositions may be derived from the same theme or motif by development along different lines, the basic theme remains the same In fracture treatment the theme is the principle involved the different methods are merely the development of that theme

In the succeeding pages will be discussed the manner in which, and the extent to which, each of the basic means carries out the principles of fracture treatment, the combinations and variations of them which are possible and the general features of the technic employed in each

Reduction by Manipulation

This method may be carried out manually, by the use of mechanical aids such as fracture tables of various sorts (Albee, Hawley, Bell, etc) or one of the various reduction apparatuses (Haynes, Stader, Griswold Roger Anderson), or by a combination of manual and mechanical means *It is generally agreed today that when a reduction apparatus is used it should be applied to complete the reduction after as much correction as possible has been secured by manual means*

1 The manipulative procedures by any of these methods involve the use of traction on the distal fragment in the line of the proximal one, rotation of the distal fragment into the axis of the proximal one, and angulation and direct manipulation of both fragments as indicated

2 It is to be kept in mind that force may be necessary, but that violence is unjustified and unnecessary

3 Traction on the humeral shaft is most effective with the elbow flexed and the arm at the side, on the forearm with the elbow flexed, on the femur with the hip and knee moderately flexed on the bones of the leg with the knee well flexed, for ankle fractures with the knee flexed to a 90° angle Muscle tension is thus avoided

4 Rotation of the distal fragment should be in general to the midposition in humeral fractures, to full supination in upper-third forearm fractures, midrotation in middle-third forearm fractures, and midposition or pronation in lower third forearm fractures, full internal rotation in femoral neck fractures, midposition or slight internal rotation in the intertrochanteric type, and external rotation in femoral shaft fractures The rotation alignment in fractures of the bones of the leg, including those involving the ankle, demands that, with the foot at about a right angled dorsiflexion with the leg, and in slight (weight bearing) inversion, a line from the anterior superior spine through the center of the patella strike the base of the second toe

5 Where length is difficult to obtain by traction alone because of loss of tissue elasticity or because of unfavorable obliquity of the fracture line the principle of the toggle may be employed with advantage It should never be used without coincident traction (see under Principles of Treatment above, Fig 521)

Some of the fracture tables and reducing

apparatuses are illustrated in Figs 524-529 with explanatory captions

The reduction procedure using these mechanical aids, with or without the help of wires or pins in the fracture fragments exerted when reduction by apparatus is carried out (particularly when fluoroscopic control is employed), that many of the apparatuses are quite complicated, and that manipulations in one plane often upset what

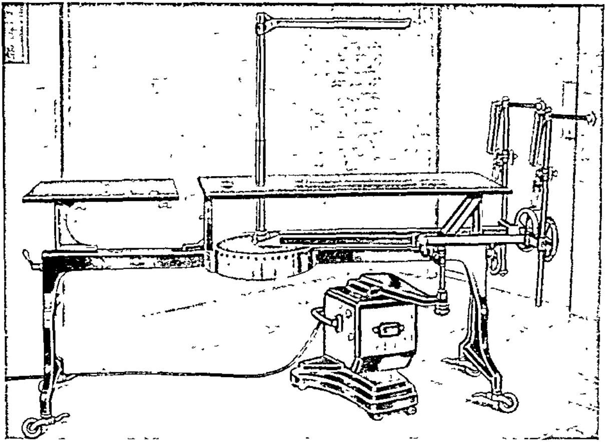
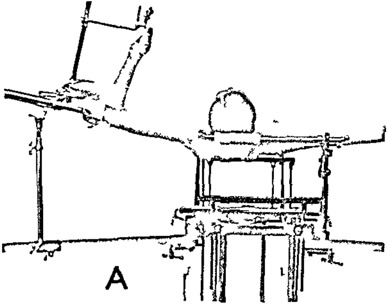


FIG. 524 Hawley Scanlon fracture table With patient on pelvic rest, lower half of table can be dropped Adjustable arms on upright provide overhead support in any position Extension leg and foot pieces can be swung around to head end of table to act as arm and hand pieces Portable x-ray unit for x-ray or fluoroscope A very flexible apparatus, providing for practically any desired manipulation, and relatively simple in construction.

differs in no way from that used in wholly manual reduction except that the procedures may be made more forceful, the control of individual movements may be more exact, the reduction attained may be held by the apparatus until the fixation element is firmly applied, and both reduction and fixation are accomplished with a minimum of assisting personnel On the other side of the ledger there is the fact that it is difficult to estimate the amount of force being has been previously accomplished in another

Reduction by Traction-suspension

As the term implies, two distinct forces are used in the attempt to secure reduction of the fracture with a minimum of violence to the tissues in as short a time as possible. It is metaphorically an attempt to "wish" the fragments into position *Longitudinal* traction force is designed to secure normal



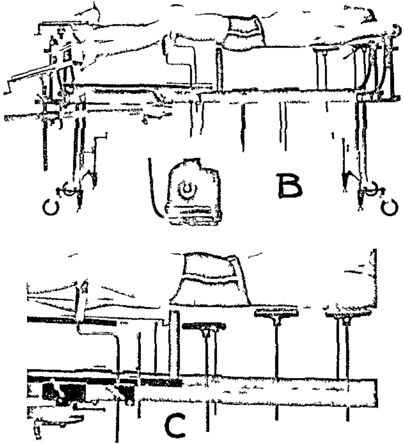


Fig 525 Bell table Patient can be supported on the adjustable board slats on a canvas strip with the boards dropped out of place or on a pelvic rest with the boards dropped out of place An overhead frame detachable is also available Adjustable leg and foot pieces can be swung to head of table and used for upper extremity as seen in (A) In (B) they are being used for lower extremity In (C) an x ray tube is in place for x ray of a hip the casette can be placed on the dropped board slat Later models have a built in casette holder The apparatus is a very flexible and satisfactory one allowing of variations to meet practically any indication

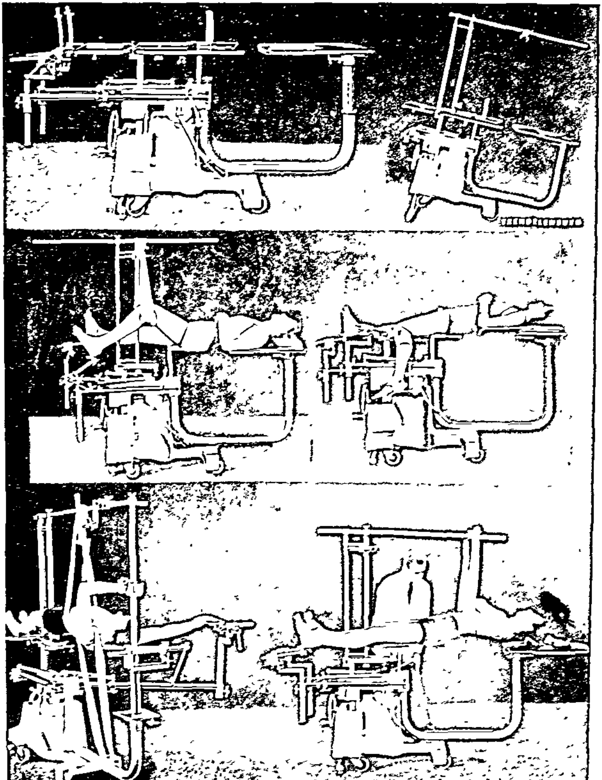


FIG 526 Albee Compere table This is a very flexible unit adaptable to almost any situation It is highly suitable as an actual operating table is subject to longitudinal or lateral tiltings is built to accommodate x-ray in any position and can meet practically any orthopedic or fracture demands It is perhaps somewhat elaborate but it cannot be too highly recommended.

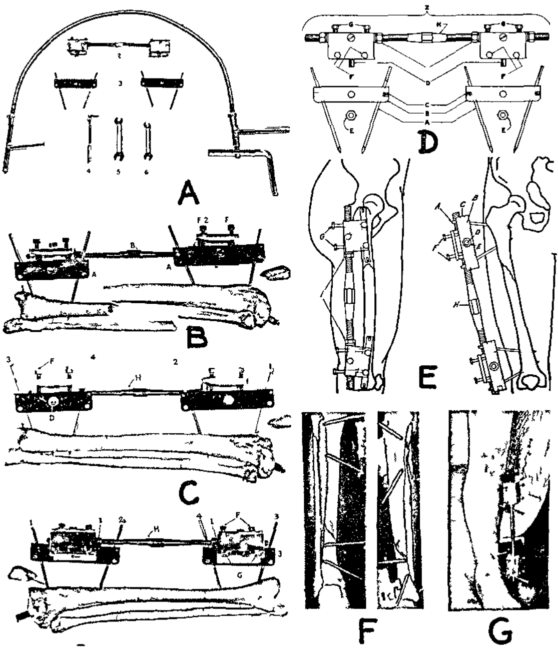


FIG 527 Stader apparatus for reduction and fixation of fractures

(A) Splint and instruments necessary for its application (1) Flexible shaft drill (2) adjustable connecting bar assembly (3) pin units (4) universal wrench for locking pins into pin bar (5) and (6) wrenches for locking of nuts and activating bar and screws

(B) To correct displacement loosen adjusting screw F 1 and screw down F 2 (A) Pin unit (B) turnbuckle

(C) Stader splint viewed from both sides showing mechanical application to tibia Pins number 1 2 3 4 in order of their insertion into bone (D) Bolt connecting half pin unit to adjusting mechanism (F) adjusting screws which control pin bar and fragment in opposite plane (H) turnbuckle (I) lock nut to secure turnbuckle to adjusting mechanism

length by stretching the muscles, and to crowd the ends of the fragments together by the circumferential pressure of the stretched muscles. In addition, *latitudinal* traction may be employed to aid in crowding the fragment ends together or to correct rotary displacements. The suspension element is designed to secure alignment of the longitudinal axes of the fragments in both anteroposterior and lateral planes, correcting angular deformities. It aligns the distal fragment with the proximal one, so that the effects of traction are exerted on fragments whose longitudinal axes are parallel.

The application of the traction force is somewhat different in the early case from the late case. The early case is one seen before the soft parts, more particularly the muscles, have become infiltrated and inelastic in their shortened position, and when muscle spasm and contraction are the factors to be overcome. It is difficult to put any definite time limit on this period Depending upon the severity of the injury in terms of soft-part trauma, on the amount of deep hemorrhage, and on the adequacy of first-aid handling and splinting it varies from 4 to 24 hours after injury. It averages probably 8 to 12 hours—but the average figure is of little use in evaluating the individual case. Inspection of the extremity and palpation of the tissues are the criteria upon which one decides whether the case shall be judged early or late. If the swelling is not extreme, and if the tissues are not brawny and indurated, the case is an early one.

In these cases one applies enough, *or more than enough,* traction to secure normal length within the next four to eight hours. *Overpull is not to be feared in these cases if it is corrected by reduction of the traction force before the tissues lose their elasticity by reason of infiltrating hemorrhage and exudation.*

If overpull is allowed to continue until this hardening of the tissues has occurred, distraction of the fragments will persist, and delayed or nonunion may result.

It is to be kept in mind that underpull is as hard to correct as is distraction, after the tissues have lost their elasticity, but that both are easily corrected before that time.

X-ray, fluoroscope, or mensuration check as to the regaining of normal length should be made preferably within four hours, certainly not later than eight hours, after the application of traction During this time the patient should be adequately sedated

If overpull is present it can be corrected by diminishing the traction force. If underpull is apparent the traction force is increased as indicated.

If normal length is secured within this time, but adequate contact of the bone ends is not attained despite adjustment of the suspension mechanism or of coincident latitudinal traction forces, the administration of an anesthetic to the patient as he lies in traction will often allow of the completion of accurate reduction by gentle manipulation of the fragments. If delayed until the

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(D) Schematic drawings of Stader reduction splint. (A) Stainless-steel pins, (B) pin blocks, (C) set-screw locking pins, (D) hinge bolt, (E) nut attaching pin block to hinge bolt, (F) mediolateral adjusting screws, (G) anteroposterior adjusting screws, (H) adjustable connecting bar, (I) lock nuts locking bar H, (Z) adjustable connecting bar assembly.

(E) Schematic drawings of femoral splint. (A) Stainless-steel pins, (B) pin blocks, (C) set-screw locking pins, (D) hinge bolt, (E) nut attaching pin block to hinge bolt, (F) mediolateral adjusting screws, (G) anteroposterior adjusting screws, (H) adjustable connecting bar, (I) lock nuts locking bar H, (Z) adjustable connecting bar assembly. Note upper pins emerging through opposite cortex and below lesser trochanter.

(F) Anteroposterior and lateral x-rays of reduction of tibia with splint applied.

(G) Appearance of splint in place after reduction.

It is a matter of importance that all rotary displacement of the fragments must be reduced before application of this splint. No correction of rotation is possible after its application.

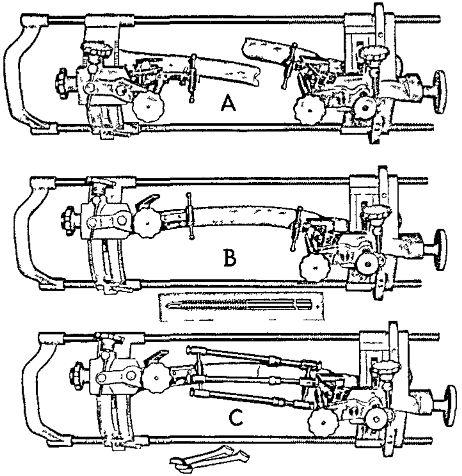


FIG 528 Haynes apparatus for reduction and fixation of fractures (A) Pin units applied and in the reduction apparatus in an unreduced fracture (B) Reduced fracture (C) The two pin units joined by the fixation bars Frame can now be removed Inset between (B) and (C) shows threaded type of pin used with this apparatus It gives relatively rigid fixation Mechanism of reducing frame works very easily and is not unduly complicated While the author does not use this type of fixation very frequently, preferring open reduction and internal fixation where possible, he prefers this apparatus to others

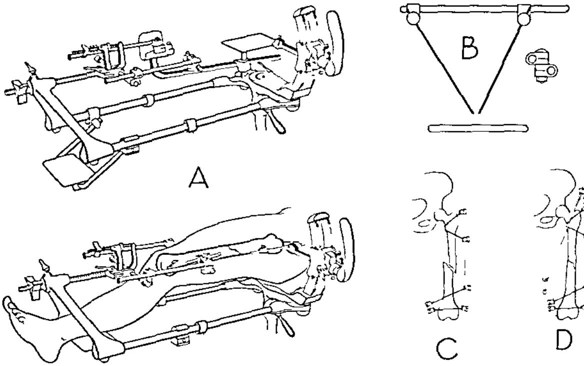


FIG. 529. Roger Anderson apparatus: (A) represents reduction machine and its application to a femur by means of the pin, bar, and clamp arrangement shown in (B) and (C). Two pins are placed in each fragment, at an angle with one another as shown in (C), and joined by a bar clamped with single nut clamps (B) Bars of upper and lower units so formed are then clamped respectively in upper and lower arms of apparatus. By an ingenious mechanical arrangement the correction of displacements in anteroposterior, side-to-side, angular, and rotary directions can be accomplished Positions secured in any of these planes can be locked. When full correction is secured the two units are locked together by one or more bars using a double nut clamp which allows of universal joint action in its application, and which can be locked when bar is in desired position on the two units. Extremity can then be unclamped from machine, locked bar and pin units holding position fixed (D). Additional rigidity of fixation can be secured by using pins which emerge from both sides of limb with bar units attached, by additional crossbar units which can be built up readily by reason of the flexibility of arrangement made possible by the universal joint action of the double nut clamps joining the bars, or by incorporating pins and attached bars in a thin circular plaster which leaves joints free. This is often desirable. Units are available for all long bone fractures as well as for special fractures such as those of jaw, os calcis, etc. Reduction machine allows of fluoroscopic control As much gross reduction as is possible should be accomplished manually after pin units are placed and before machine is applied, and the latter then used for correction of remaining displacements

soft tissues have become infiltrated and relatively rigid such manipulation may well prove unsuccessful and even if successful will have to be more forceful to accomplish its purpose This combination of the early coincident application of two methods of reduction will often prove successful when either method alone will not

Reduction in early cases by traction suspension should be checked by the hour—not by the day or by the week

The principle of reduction before the pathologic changes in the tissues become fully established—i e early reduction—whenever possible is just as sound for traction suspension as it is for closed manipulation operation or any other method of reduction

If it is felt that a large amount of weight will be necessary to secure normal length within a few hours as in a fractured femur in a husky individual it is wise not to apply the full weight all at once since the sudden heavy pull on spastic muscles may cause pain and additional spasm It is much more effective to apply 10 or 15 pounds immediately and to add increments of 10 pounds additional weight every 20 or 30 minutes until the required amount is applied

The common practices of delaying the application of traction suspension as a means of reduction in early cases until a convenient time and of checking on its effects only after 18 24 or 48 hours have passed are responsible for many of its reputed inadequacies and failures Actually however these results are to be laid to using the method in violation of principles and not to the inadequacy of the method Properly used it is not an easy method It is the least traumatizing of reduction methods and if it is coincident with moderate elevation constant low grade heat to the part and gentle stroking massage during the early hours while reduction is gradually being accomplished the progress of the pathologic change in the soft parts can be materially slowed and the dispersal of the pathologic products of tissue damage can be materially hastened

The organization of the average hospital will not allow of the adequate carrying out of all these details Certainly however if it is to be used every attempt should be made to carry out the application of the principles involved to the full extent of the institution s ability If it cannot be used to carry out even the basic principles on which it rests some other form of treatment which can be more adequately carried out is to be preferred

In the late cases—those seen after the tissues have lost their elasticity by reason of infiltration by hemorrhage and exudate—rapid reduction within a few hours without damage to the tissues is not logically possible if the displacement and loss of length are anything more than mild *In these cases overpull must be carefully guarded against* since the inelastic tissues will not allow of its correction Moderate traction 8 to 15 pounds at the most should be applied and should be gradually increased up to the amount necessary to secure normal length as the tissues approach their normal elasticity

The regaining of normal elasticity is accomplished by dispersion of the accumulated hemorrhage and exudate in the soft parts through elevation and the physical methods described for the early cases It should not be left merely to time and chance Its progress should be checked clinically by frequent inspection and palpation of the soft parts

When normal length has been almost regained the aid of discrete manipulation under anesthesia in traction suspension should be resorted to to complete the reduction Dependent upon the amount of soft part pathology present this procedure may take 24 48 or 72 hours It should never take more than three or four days at the most if it is to be really effective If adequate reduction has not been secured by the combined methods in that time some

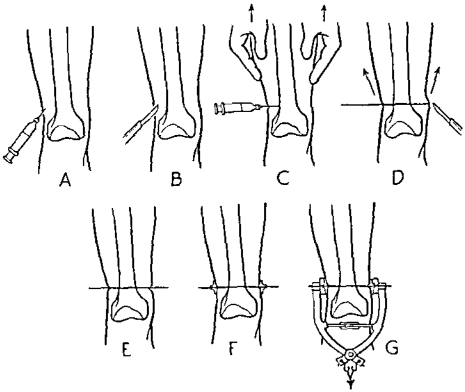


FIG. 530. Technic of insertion of pins and wires. (A) Novocaine bleb is raised. (B) Skin nick. (C) Skin pulled upward while novocaine is injected down to and into periosteum. Similar injection is made on opposite side. (D) With skin pulled upward wire or pin is inserted until point presents beneath skin on opposite side. Skin is marked over point and pin is driven through. (E) Pin in place with upward pull on skin released. (F) Thin cotton collodion dressings applied. (G) Felt pads between sides of yoke and dressings to minimize chance of slipping.

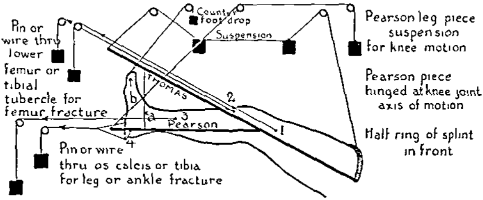


FIG. 531. Skeletal traction, utilizing a Thomas splint and Pearson leg piece, applied to (1) femur, (2) tibial tubercle, (3) lower tibia, (4) os calcis. If knee-joint movement is not desired, Pearson leg piece can be clamped to suspension splint at any desired angle (a), or a Braun frame can be used instead of the splint and leg piece. Suspension foot piece (b) prevents footdrop.

other method mechanically more effective should be resorted to without further delay, if any such is available or feasible in the individual case Delaying the change of method for two, three or four weeks, as is frequently done, serves no good purpose it merely increases the handicaps which an traction-suspension is initiated, failure to elicit evidence of bony contact between fragments by crepitus during the course of application of the apparatus should arouse suspicion of tissue interposition, and failure to obtain such evidence by discrete and gentle examination after a few hours of

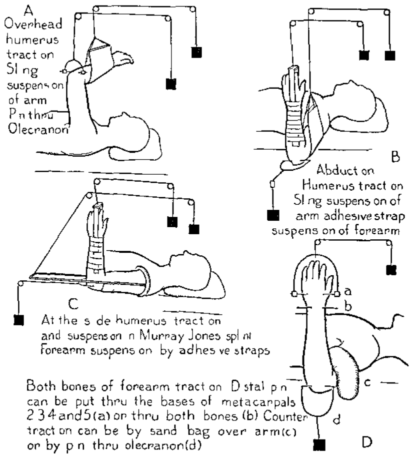


FIG 532 Skeletal traction in upper extremity, as applied for both bones of forearm (D), and for humerus (A, B, C)

alternative method of reduction must overcome

Interposition of tissue between the fragments is a not too uncommon cause of failure of reduction by traction suspension Its existence is too often recognized only by reason of failure to obtain x ray evidence of contact of the fragments after several weeks of treatment, or by the ultimate evidence of nonunion At the time traction should make one consider the possibility very seriously Necessary operation within a few days is a far preferable, easier, and more successful procedure than is operation after a few weeks or, ultimately, for a nonunion

Traction suspension may be used with variations employing traction of several types—skin traction, Russell traction, skeletal traction, and fixed traction In general,

skeletal traction is more efficient and accurate mechanically than any of the other three forms, but entails more risk of complications such as infection and pin accidents. The general technic for the commoner variations of the different types of traction-suspension are illustrated in Figs. 530-539.

Open Reduction

This method must follow the general principles involved in all reductions. A large part of the general reputation which it bears as a method leading to delayed and non-union and prone to be followed by infection is directly attributable to the fact that it does not properly carry out principles as commonly employed.

The use of open reduction is indicated in accordance with the following criteria:

1. Operation by Virtue of Necessity.
   a. When other methods have failed to secure adequate reduction or it is obvious or known that they will so fail. The important point here is to come to this decision early and to restore the soft parts to as nearly a normal state as possible before operation. The third and fourth week after fracture represent the period of maximum decalcification in the vicinity of fracture, and the period during which adequate fixation is most difficult to attain. The decision should be arrived at certainly within the first ten days, better within the first two or three days, and ideally within the first 12 hours after fracture. Very commonly open reduction is resorted to only after two, three, four, or more weeks of various attempts at more conservative management. There is little excuse for expecting, in this instance, results comparable to those which can be obtained when the procedure is used within the first few hours, or even within the first few days.

   b. There is a group of fractures in which operative treatment is generally recognized as the only effective method. In these, primary operation is indicated subject to all the dicta set down here-

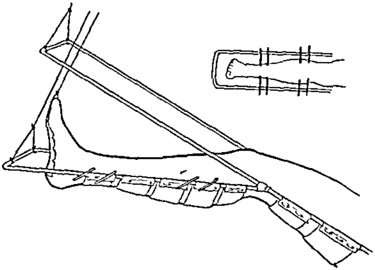


Fig 533. Fixation after traction in Thomas splint—Pearson leg piece arrangement, allowing limited mobilization of knee joint. Reduction is accomplished by skeletal traction as illustrated in Fig. 531, with both sets of pins in place, or by manual means, or by a combination of the two, and pins are then clamped to bars of Pearson leg piece. Knee joint can be fixed or mobilized as desired.

after (1) Fractures of radial head or neck with displacement of fragment or fragments in adults (2) Fracture of patella with separation of fragments

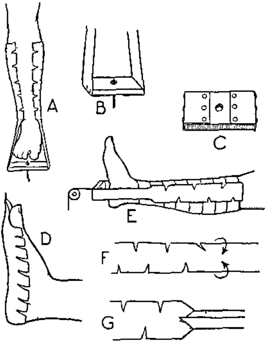


FIG 534 Details of skin traction application (A) Skin traction straps of moleskin adhesive Dotted line indicates overlying Ace elastic bandage (B) and (C) show details of fastening traction straps to wooden spreader with thumb tacks (D) Foot piece of adhesive with overlying Ace bandage (F) and (G) illustrate method of making traction straps Dotted rectangle in (G) represents a reinforcing piece of adhesive to minimize tearing at edges of strap Note that upper end of adhesive strap is not covered by bandage so that any tendency to slip can be easily noted that Ace bandage does not extend to crease of joint below and that nicks in adhesive help to make it conform readily to shape of leg

(3) Fracture of olecranon with separation of fragments (4) Fractures of anatomic neck of humerus with dislocation of head fragment (5) Fractures involving joints in which a loose fragment lies within a joint (6) Fractures in which the fragment represents an avulsion of a muscle or tendon attachment which must be replaced and is not amenable to conservative measures A fracture of greater tuberosity of

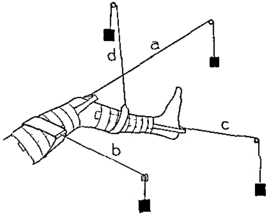


FIG 535 Latitudinal and torsional traction For latitudinal traction a complete nonadherent loop is used well padded as shown in (b) Variation in direction of pull allows of correction in any direction without rotation For torsional traction an adhesive strip is used as shown in (d) for its effects on one or both fragments (a) and (c) represent longitudinal tractions for femur and leg respectively

humerus pulled up under acromion by the supraspinatus is a representative of the group The lesser trochanter of the femur is not as its displacement apparently has little if any functional effect (7) Cases with interposition of tissue preventing closed reduction

2 Operation as the method of choice even though more conservative methods may be capable of securing satisfactory reduction To justify operation under these circumstances there must be advantages warranting the procedure apart from the accomplishment of the reduction These may be

a Making possible internal fixation which will allow of more certain union and/or a lessened mortality risk (e g hip fractures and certain compound

fractures), or shorter disability time and earlier return to function (e.g., adult long-bone fractures, some ankle fractures, some joint fractures, etc. See Maintenance of Reduction and Immobilization by Internal Fixation, below).

b. Added ease and increased chance of success in dealing with coincident soft-part injuries (e.g., nerve and tendon injuries, compounding wounds).

In electing operative reduction over effective conservative means, the surgeon assumes the responsibility for making sure that the theoretical advantages of the former can be translated into actualities without increased risk to the limb or the life of the patient. To insure this requires meeting fully and adequately all the demands created by the criteria detailed below. If this cannot be done, operation as a method of choice is not justifiable.

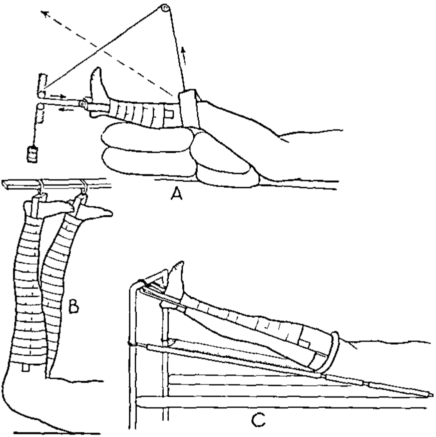


FIG. 536. (A) Russell traction. (B) Bryant overhead traction. (C) Le Mesurier traction. Leg is supported by pillows in Russell traction. In Le Mesurier traction patient lies on a Bradford frame which is fixed at an incline to foot of bed. The Thomas is fastened to foot rail and traction straps are fastened to the Thomas. Patient's body weight acts as his traction force on inclined plane of Bradford frame.

When the operation is done by virtue of necessity those criteria also should be met insofar as is humanly possible, even though complete compliance with their demands cannot be accomplished.

Open reduction should be performed, in the cases in which it is indicated, before the pathologic process in the tissues has become established, if possible. That is usually within 8 to 12 hours after injury. Every hour earlier that it can be done is a distinct advantage. There is less bleeding in this

early stage the reduction is more easily accomplished the risk of infection is less and the operative exposure allows the es cape and removal of surprisingly large amounts of hematoma fluid exudate and

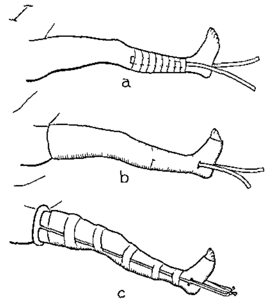


FIG 537 Tobruk plaster with trac tion This is essentially designed for transportation and has been extensively used in military operations It is how ever adaptable to civilian practice Ad hesive traction straps are attached to leg and a thin nonpadded circular plaster is applied from groin to toes after cor rective manipulation and while traction is maintained on straps Straps emerge at ankle portion of plaster (a and b) A Thomas splint is then sl pped over the extremity and traction straps fastened to foot of splint to maintain traction (c) Thomas splint and plaster encased extremity are then included in several circular plaster turns

devitalized and dead tissue Once the patho logic process following fracture is fully established all this material is more or less fixed in the tissues which thereby lose their elasticity The reduction becomes more dif ficult and the bleeding more marked because of this loss of tissue elasticity The local circulatory stagnation due to infiltration of the tissues increases the risk of infection and the removal of the infiltrated hemor rhage and exudate constitutes an added burden on the local minute circulation The rapid removal by the earlier operation of the pathologic accumulations before they become fixed in the tissues minimizes this burden and plays no little part in aiding the rapidity and certainty of bone repair

If the pathologic process is already com plete by the time the case is seen or will be so by the time for one reason or another it can be operated on it is much wiser to devote the necessary time to elimination of the pathologic accumulations in the tissues before operating Adequate immobilization moderate elevation constant low degree heat in any form massage even the use of the positive and negative pressure boot where feasible or the use of brachial or paravertebral block will have the tissues restored to a relatively normal consistency within anywhere from one day to one week It rarely takes the latter period Two to four days represents the average time needed

With the tissues again relatively elastic and with the local circulatory stasis relieved and tissue tension markedly diminished the reduction again becomes easier and bleeding and the risk of infection less than in the intermediate stage Much of the pathologic infiltration of the tissues how ever remains to be dealt with which could have been eliminated had operation in the early stage been possible

The mere application of an immobilizing splint and waiting for a routine set number of days before operation as is a common practice is a fallacious and defective inter pretation of this principle The time to do the delayed operation is as soon as the tis sues are restored to a relatively normal consistency with relatively normal circula tory efficiency by active therapeutic meas ures—not after the routine lapse of a set number of days of passive waiting

Operation for one reason or another may be vital and necessary in the intermediate period If so it should be recognized that this is regrettable and unfortunate

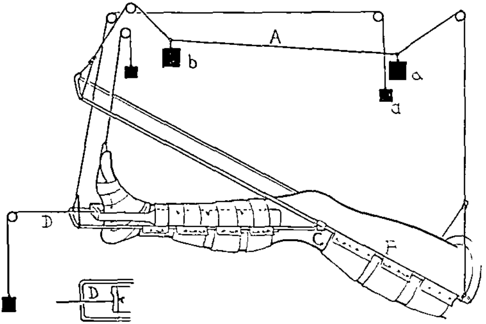


FIG. 538. Details of traction-suspension apparatus needing frequent check (A) Suspension is preferably by a divided weight increment, half at upper end and half at lower end (a and b) Combined weights should be such that when patient is lifted, as for a bedpan, splint as a whole should rise with him without changing its relative position to patient. This is easily tested at time of application. Adding to proximal weight (a), or shifting it closer to proximal suspending pulley, raises ring from patient's thigh without materially altering position of distal end of splint. Decreasing weight, or shifting it distally from pulley, lowers ring Adding to distal weight (b), or shifting it toward distal suspending pulley, elevates distal end of splint without materially affecting position of ring. Ring placed anteriorly, avoiding buttock area, for nursing convenience. Decreasing this weight, or shifting it proximally from distal pulley, lowers distal end of splint. Thus total counterbalancing effect, angle of splint to body, and proximity of ring to patient's thigh can be independently controlled. Extremity rests on flannel or light canvas strips, individually adjustable so that contour of extremity can be smoothly followed, preventing points of pressure and circulatory interference. Safety pins are used in illustration (B) but heavy paper clips, etc, can be used. Several fastenings for each strip allow accurate adjustment. A strip of moderately thick padding is laid over this flannel bandage bed to further guard against point pressure Pearson leg piece can be fastened at any desired angle (C), or can be mobilized by a weight through overhead pulleys to within reach of patient's hand (A-d) Thigh and leg should be bandaged into splint separately, leaving knee uncovered. Traction should be parallel to suspending splint, and down its center (D). Splint and all suspending weights should hang free Any knots in cords and all spreaders should be kept from contact with pulleys to avoid loss of traction Traction cords should be free from contact with anything except pulleys. Impingement against end of splint or elsewhere reduces traction by friction interference (D). Pearson leg piece should be attached at knee-joint axis (except in supracondylar femur fractures when it should be at fracture site). Periodic checks should be made several times daily on: (1) Ring—hand should just be able to pass between all portions of ring and thigh, and ring should not press into perineum; (2) suspending bands—should present a smooth surface to passing hand, without wrinkles, tight edges, or ridges, (3) level of leg-piece hinge; (4) line of traction in regard to suspending splint; (5) angle of elevation of splint, (6) slipping of traction straps (see Fig. 534); (7) free hanging of all weights and of splint assembly; (8) impingement of knots or spreaders on pulleys; (9) correct balance when bedpan is used; (10) freedom from pressure on bony points by traction straps; (11) absence of friction points. Using hands and eyes, these checks take but a few seconds if they are made routine as part of all nursing care of patient and are made frequently; (12) position of patient in bed. This should be as constant as possible. A marker is put on suspending frame and a trapeze hung at patient's arm level so that he can keep himself properly placed in bed. Knee gatch should always be elevated before head is raised to prevent slipping down in bed. Elevation of foot of bed serves as countertraction.

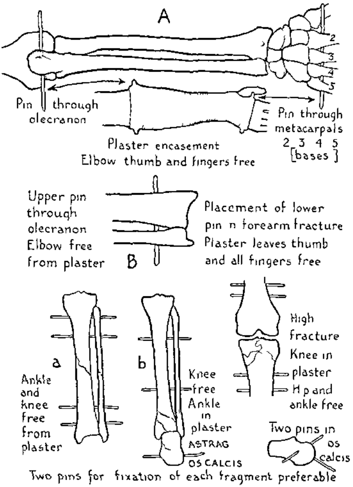


FIG 539 Methods of pin and plaster traction fixation (A) Colles fracture Used when comminution is so severe that position cannot be maintained by ordinary splinting Both elbow and fingers are free Can also be used for forearm fractures Manipulation performed with pins in place, which are then fixed in plaster (B) Both bones of forearm Upper pin or pins through olecranon Lower pin or pins are passed through ulnar side, transversing ulna first and then radius, and are placed with lower fragment in pronation for lower third fractures, in midposition for middle third fractures, and in supination for upper third fractures Reduction then accomplished and pins incorporated in plaster encasement, leaving elbow and wrist free No pronation or supination possible (C) Both bones of leg and ankle fractures Pins placed as in (a) or (b) as indicated by location of fracture, reduction completed, and pins held by plaster Knee free in either instance, ankle free in (a) but not in (b) In fractures close to knee joint, pins can be placed in tibia below fracture, and in femur above condyles Knee immobilized, but ankle and hip free, plaster extending from supramalleolar region to groin

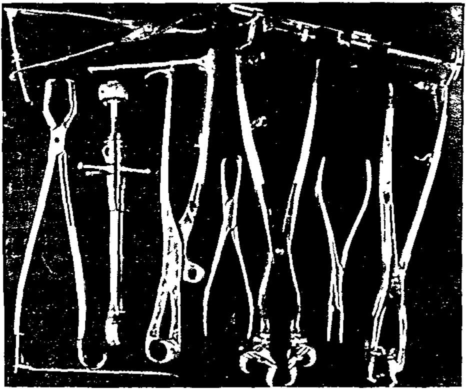
The operative approach should be by the longest incision possible, between muscles and not through them whenever possible, and it should be deepened to bone with as little stripping of soft parts as possible. The length of the incision does not affect the healing. Wounds heal from side to side, not from end to end. The long incision does allow, however, of adequate exposure with a minimum of traumatizing retraction and additional tissue damage, and adds to the ease of reduction and the quality of both wound healing and resistance to infection.

The exposure of the fragments should be accomplished by splitting and stripping periosteum from bone, not by stripping soft parts from periosteum. The periosteal circulation is derived from the surrounding soft parts, and not from the bone. There is no intrinsic periosteal circulation. When soft parts are stripped from it, it remains an avascular membrane between soft-part circulation and bone until its circulation can be re-established. The obviousness of this is apparent in compound fractures in which it is impossible to cover with soft parts the intact periosteum over one or both fragments. Within a few days such periosteum sloughs as does an exposed tendon, and for the same reason.

When reduction has been accomplished, the periosteum offers vascular coverage for the fracture site directly in contact with bone if its soft-part connections have been preserved. It is quite important, then, that the long incision be used to allow of approach to the bone with a minimum of soft-part retraction and stripping, and that the actual bone exposure be made by splitting and elevating the periosteum to the required extent.

The exposed fragments and the x-ray should be carefully studied so that the manipulations necessary for reduction may be minimized and efficiently accomplished with a minimum of violence. Adequate armamentarium in the way of bone-holding clamps, skids, and elevators is essential, and an assistant who can aid by intelligent handling of the extremity (and whose sole job this should be) may be invaluable in helping to accomplish reduction with a minimum of violence and a maximum of efficiency. True enough, reduction can be accomplished with no special equipment and with no assistant aiding by handling the extremity during the reduction—but it is not apt to be a reduction according to principle. It does not "wish" the fragments into place; it bludgeons them into place. It secures an "x-ray reduction," perhaps, but the x-ray does not demonstrate the damage done in securing it.

In operating on a fresh or recent fracture we are dealing with damaged and devitalized tissue having a handicapped circulation To minimize the risk of infection we must do two things—reduce to an absolute low the possibilities of carrying organisms into this devitalized field, and inflict as little further damage on already impaired tissues as possible. Skin preparation should be detailed and careful. Rigid exclusion of all skin surfaces and edges from the operative field by adequate draping is essential. The tissues should be gently handled. Hemostasis should be thorough, the smallest possible hemostats should be used, and as little tissue as possible should be included in their grip. Fine ligatures, preferably of silk, should be used for ties, or the cautery current can be employed. The hands, or things which have touched the hands, should be introduced into the wound as little as possible. A rigid "no-touch" Lane technic is ideal. It is often impracticable. An approach to it is always possible—the nearer the approach the better. If the operator will imagine that everything used at the operation—drapes, gloves, gowns, instruments, sutures, and ligatures—are grossly contaminated, and that his dual job is to introduce as little of that contamination into the wound as possible and to leave the tissues



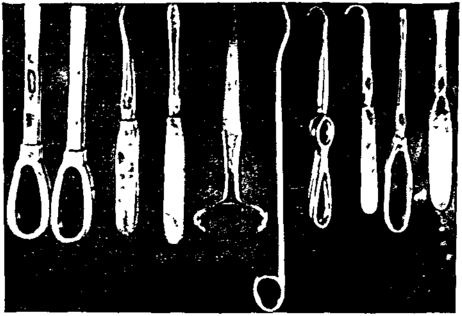


FIG. 540 (*Top*) Various types of bone clamps for use in securing and maintaining reduction of fragments while internal fixation is being applied There are various sizes of each clamp Among those shown are the Magnuson the Bendixen the Lambotte the Heitz Boyer the Jackson and the Lowman Several ordinary bone holding forceps are shown A wide variety of clamps is an essential part of the operative armamentarium

FIG. 541 (*Bottom*) Various elevators and skids of use in carrying out open reductions On left are two views of the Darrach elevators Dorsal surface is knurled and anterior face is slightly spooned It has a medium sharp edge and functions as either an elevator or a skid In the middle is the familiar sawtooth skid and to its right is the Lane skid the blade of which has numerous small perforations Bone hooks (sharp and dull) and other types of elevators are shown

in the best possible shape to combat that which he does introduce, a satisfactory technic will be the result.

Open reductions done in this fashion so as to carry out sound principles are not dangerous, do not lead to delayed or non-union, and inflict less additional damage on the part than do many closed and double-pin-traction manipulation procedures. It is to be distinctly understood, however, that *unless open reduction can be carried out as here described it should be performed only by virtue of necessity and not as a matter of choice.* Even when done as a matter of necessity, the utmost effort should be made to approach as nearly as possible the ideal procedure.

Figs. 540 and 541 demonstrate some of the instruments which are of value in meeting the various mechanical situations encountered in open reductions.

MAINTENANCE OF REDUCTION AND IMMOBILIZATION BY EXTERNAL FIXATION

This may be accomplished by the application of plaster to the part, or by the incorporation of pins in or through the bone in such plaster or in some form of fixation splint. The plaster-and-pin method is illustrated in Fig. 539. The fixation splint methods are illustrated in Figs. 527, 528, and 529.

When plaster alone is used, it may be used as molded plaster splints or as circular plaster. It is the author's practice to use closely molded plaster splints lined by can-

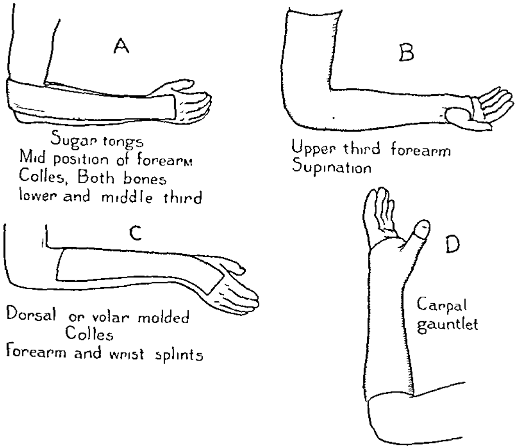


FIG. 542. Plaster for forearm and hand. (A) Sugar tongs splint. (B) Circular plaster for upper third of forearm. Can be used, as shown by dotted lines, as molded plaster splints. (C) Splints commonly used for Colles fracture. (D) Wrist gauntlet as for carpal navicular fracture.

ton flannel which can be adjusted frequently if necessary by loosening or tightening the bandages until all swelling has subsided and then to include them in a light circular encasement or to replace them by circular plaster If circular plaster encasements are used primarily as is the practice of many men they may be used with or without padding The unpadded plaster is becoming more and more popular Careful and accurate molding is called for in the use of circular plaster to avoid localized pressure points and particularly so in the use of unpadded plaster When circular plaster is applied as the primary method of immobilization it is usually considered wise to cut the plaster for its whole length immediately after it is applied so that it can be easily spread if swelling beneath renders it dangerously tight

Following are a few other general precepts for the use of plaster which are worth noting

1 All molding of plaster should be done before the plaster begins to show the first evidence of hardening Molding after this time merely breaks up the crystallization process and leads to weak plaster tending to crack give and soften

2 Following the application of plaster particularly of molded splints position should be maintained until the plaster is sufficiently hard to take up the job Many reductions are lost during or after splinting by failure to observe this practice Depending upon the plaster and other conditions this may cover a period of from 10 to 30 minutes

3 Do not use a heat lamp to hasten the drying of plaster on an unconscious patient Severe burns may result from steam within the wet plaster

4 Make a frequent check on the circulation after the application of plaster during the first 24 hours It is a good idea to have printed directions on this score to give to the patient who is not going to be under observation so that he will know what to do in the event of untoward developments

5 Instruct the patient *by demonstration* in the joint movements he is to perform and in whatever muscle exercise without joint movement he is to carry out in order that the method may come as near as possible to carrying out the principles of treatment Give him a definite time schedule

6 In addition to the x ray check taken immediately after reduction and splinting have an additional check in 24 or 48 hours and again before the end of a week Most losses of reduction will be picked up by this practice in plenty of time to allow of correction without difficulty

7 If molded splints are used check the bandaging daily for the first week Accurate adjustment of the splints as swelling diminishes will lessen the chance of loss of position

Figs 542 544 illustrate some of the commoner forms of molded splints and circular plasters

Maintenance of Reduction and Immobilization by Traction suspension

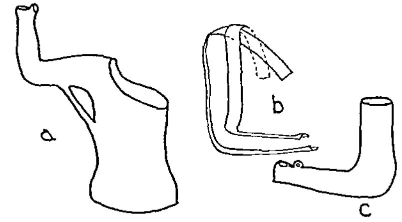
When used as a means of maintaining reduction and of securing fixation at the fracture site traction suspension must be modified somewhat from the way in which it is used for reduction purposes

Only enough weight is used to maintain reduction and overpull is carefully guarded against by frequent clinical and x ray check

Molded plaster splints coaptation splints or thin plaster encasements are used as adjuvants to aid in the insuring of adequate fixation at the fracture site

Unless plaster encasements are used the extremity with the splints used as adjuvants is snugly held in the suspension apparatus under muslin flannel or woven elastic bandages with liberal padding

Mobilization of joints by any of the methods illustrated is kept distinctly within discomfort limits and within limits not calculated to disturb the fixation at the fracture site (Fig 531)



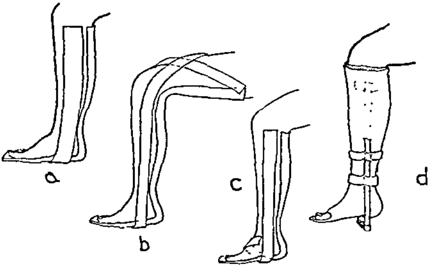


FIG. 543. (*Top*) (a) Shoulder spica in abduction and external rotation. By dropping forearm to horizontal, abduction and internal rotation are secured. Spica comes down well over iliac crest. (b) So-called elephant ears splint for immobilizing shoulder or humerus. (c) So-called hanging plaster. Greatest weight of plaster is at elbow and suspension must be entirely from wrist so that weight of plaster acts as a constant traction force on humerus. A ring is set into the plaster at wrist to insure this traction.

FIG. 544. (*Bottom*) Plaster for ankle and leg. (a) Posterior molded and sugar tongs below knee for single malleolar fractures at ankle. (b) Posterior molded and sugar tongs above knee for bi-malleolar or Pott's fractures or fractures of both bones of leg. (c) Posterior molded and Stimson splint for ankle fractures. (d) Walking plaster. This must be well molded in to condyles of tibia so that weight is borne by tibial condyles.

The various modalities of physical therapy are used during the healing period to the fullest possible extent consistent with comfort of the patient and adequate fixation at the fracture site They are considered however merely as adjuvants to and inadequate substitutes for active use of the muscles

When active function of joints cannot be practiced exercises in muscle contractions without joint movement are cultivated

Maintenance of Reduction and Immobilization by Internal Fixation

This method of immobilization of the fracture fragments follows open reduction with the exception of fractures of the upper end of the femur where it is often used in conjunction with a closed reduction of the fracture itself There are numerous methods of internal fixation The purpose of some of them is merely to hold the reduced position with varying degrees of immobilization of the fragments the major role in immobilization being external plaster With other methods traction suspension is used as an adjuvant to secure adequate immobilization With some the internal fixation is adequate for limited but progressive function with or without the aid of balanced suspension The following general guides apply to all methods

1 As little soft part damage as is possible should be inflicted during the application of internal fixation

2 The fragments should be held as accurately reduced and as firmly approximated as possible during the application of fixation This may require a variety of bone holding clamps illustrated in Figs 540 and 541

3 Any necessary stripping of tissue should be carried out between bone and periosteum and not between periosteum and soft parts

4 Encircling clamps or fixation material (wire bands etc) can frequently be placed through narrow encircling channels without marked longitudinal stripping

5 Rigidity of fixation should be evaluated before the wound is closed by means of a clamp on each fragment testing out rotation and angulation in both planes of one bone fragment on the other

6 The presence of fixation metal directly beneath the skin is undesirable and should be avoided wherever possible

7 Careful study of the mechanics of the situation in each case after exposure and reduction will lead to more efficient fixation than the adoption of a routine procedure

8 The simultaneous use of metals of different composition in fixation should be avoided as possibly leading to irritation in the surrounding tissues with resultant subjective discomfort increased risk of the development of infection and possible interference with the bone healing process

9 Metal loosely fixed in the bone or subjected to concentrated strain or exercising continuous circular compression of bone, is apt to show absorption of calcium salts about or beneath it

10 The more trauma inflicted on the soft parts surrounding metal fixation during its application the greater the chance of the development of irritative and inflammatory reaction about it

Fixation can be accomplished by the use of wire, bands nails, or plates and screws The use of catgut kangaroo tendon fascial strips silk or cotton as bone sutures for fixation has been pretty generally abandoned and in general requires justification except to meet some unusual situation This is due largely to the fact that metallic fixation can today be accomplished without appreciable risk of serious foreign body irritation if proper precautions are observed These precautions have to deal with the nature of the metal utilized and the technic of procedure and will be discussed in detail below for the various methods of fixation

Fixation by Wire This may be used for almost any fracture in the form of suture,

circumferential banding, transfixion, or intramedullary insertion. It is particularly useful in fractures of the patella, the olecranon process and the various apophyses, and in flat-bone fractures. It is frequently used in fractures of the jaws. In the long bones it calls for postoperative immobilization by plaster or traction. For suture or circumferential banding, cold drawn wire of adequate thickness of stainless steel of the general composition of 19 chrome 9 nickel or 18 chrome 9 nickel plus molybdenum, or of tantalum may be used. Two different compositions should not be used in the same patient. The minimizing of soft-part trauma during the operation by careful adherence to the technic of open reduction as described previously will help to prevent the chances of subsequent irritation in the tissues. The cut ends of twisted wire should be flattened out on the bone so that they do not protrude into overlying soft parts. It is to be remembered that circumferential wiring without fixation through drill holes at some point in the circumference of the bone is apt to lead to absorption beneath the wire, with resulting loss of fixation.

For transfixion or intramedullary use the wire has to be stiff and semirigid. Properly hardened stainless-steel wire of either of the types mentioned (in appropriate thicknesses up to that of a diameter which would perhaps be more properly designated as steel rod) are indicated. This method has been used in metacarpal, metatarsal, and phalangeal fractures, in clavicle fractures and acromioclavicular separations, in forearm long-bone fractures, in condylar- and articular-surface fractures, and for the pinning on of apophyseal fractures. This type of wire in its smaller diameters is commonly referred to as Kirschner wire, and much of it sold under that name is entirely too soft and flexible for this purpose, although suitable for use with a yoke or tautener for skeletal traction.

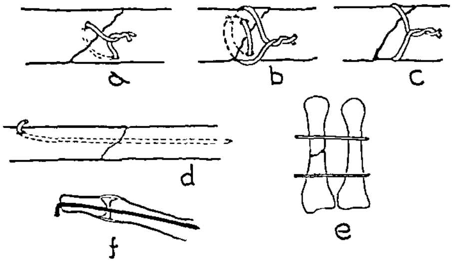


Fig. 545. Various methods of using wire for fixation. (a) Simple wire suture. (b) Suture plus encirclement with same piece of wire. (c) Simple encirclement. (d) Intermedullary wire as used for clavicle. Note bent-over end to keep wire from migrating. (e) Wire fixation as practiced for metacarpals and metatarsals, utilizing adjacent unbroken bone. (f) Intermedullary wire for fixation of acromioclavicular joint. Note bent-over end of wire at edge of acromion to prevent migration.

Common methods of suture, banding, transfixion, and intramedullary use are illustrated in Fig. 545, and are referred to or described in the discussion of the various fractures elsewhere in this book. The use

of wires for transfixion and intramedullary fixation followed by plaster or traction suspension offers a field for development

Use of Parham Band This was at one time quite a popular method for the fixation of spiral and oblique fractures of the long bones Its popularity has waned with the development of other methods Occasionally it may meet a special demand which cannot be met by standard plates and screws, nails or wire but such instances are exceptional Its theoretical advantages over the use of circumferential wiring are the broader surface of apposition to the bone, and the ingenious device used to tighten and fasten the band without the necessity for twisting It has, however, no point of fixation in the bone, it requires at least as much, if not more, stripping of tissue for its application as does wire, and absorption of bone beneath it, with loss of fixation and slipping of the band, is quite prone to occur The use of this method is not recommended

Fixation by Nails and Screws Long oblique or spiral shaft fractures of the long bones condylar and articular surface fractures of the long bones, fractures of the apophyses and malleolar fractures represent the type of lesion most amenable to this form of fixation The metals suitable for nails and screws are vitallium, either of the stainless steels previously cited, and possibly tantalum Vitallium would seem to produce the least physiologic disturbance in the tissues and much has been done in refinements of manufacture to eliminate the breakage risk inherent in all cast metal subjected to continuous strain The stainless steels are a little less inert in the tissues but are made from cold drawn rod and are more calculated to stand fatigue strain without breakage Tantalum screws present manufacturing difficulties Up to now they have been produced only on a small scale, but may turn out to be satisfactory It would seem probable at the present writing that it may be possible to successfully work vitallium instead of casting it If this should prove the case, vitallium would unquestionably be the ideal metal for all internal fixation appliances

The author s preference is for screws or nails of 19 and 9 stainless steel, but he concedes that 18 and 8 molybdenum stainless steel and vitallium are perfectly satisfactory for this method of fixation, and that tantalum probably is The design of the screw is of some importance and this and the metals involved will be discussed in more detail in the consideration of plating below Special adaptations of nails, screws and bolts have been devised for use in hip fractures (the Smith Petersen nail and its various modifications, lag screws of Henderson and Lorenzo), and for ankle and tibial condylar fractures (bolts) These are referred to, under the fractures involved, elsewhere in this book

It is the author s feeling that, except under exceptional circumstances, the use of screws alone in the internal fixation of fractures *of the shafts of the long bones* calls for postoperative protection by external fixation through the use of plaster, or for protection by postoperative traction suspension until adequate bone healing is demonstrable In the case of apophyseal fractures, condylar and articular surface, and malleolar fractures, the degree and period of postoperative immobilization must be determined on the basis of the rigidity of fixation obtained, the distribution of strain secured, and the amount of strain entailed The principles involved are developed in some detail in the discussion of plating which follows

Fixation by Plate and Screws The application of a plate with screws for fixation following open reduction of a fracture is a technically difficult and detailed procedure if properly done We desire to secure as completely rigid fixation of the fragments as possible, with as wide and equable a distribution of strain upon the plate and the individual screws as possible The

former makes feasible various degrees of active function of the part during the phase of bone healing, the latter guards against decalcification and absorption of bone around the fixation elements (plate and screws) as a result of the pressure strains which they mutually share and transmit. Direct pressure against living bone, if sufficiently concentrated and continuous, induces such absorption, and muscle tone, gravity, muscular contractions, and weight-bearing all produce such direct pressure transmission of bone against screw and plate and plate and screw against bone. This is not a theoretical statement, but is factual.

With proper regulation of the strain imposed, and adequate distribution of that strain, there should not be, and is not, any absorption in the bone about the fixation elements. If absorption does occur, it indicates that the fixation elements themselves are irritating and productive of inflammation, that the fixation is not a rigid one, that the strain being imposed is excessive either because it is not adequately distributed or because it is greater than the fixation used will allow, or that infection is present. One other factor tends to further such absorption—diffuse local decalcification of bone secondary to impairment of the circulation in the soft parts surrounding the fixation area due to excessive operative trauma

At the present writing, either of the stainless steels described under fixation by nails and screws and vitallium represent the three metals for use in plating which have been found to be productive of so little physiologic disturbance when properly placed in the tissues that they can be felt to offer no appreciable threat of damaging inflammatory action due to the metal itself. Vitallium is rather definitely the least productive of disturbance. There is little upon which to base a choice between the stainless steels cited on this score. Both show noticeably more tissue reaction than vitallium.

The steels are cold worked, the vitallium is cast. The steels are, for this reason, less subject to fatigue strain and fracture. Refinements in the manufacture of vitallium plates have cut down, and are continuing to further reduce, an earlier tendency to such fatigue strain and fracture. The probabilities are that it is possible to work vitallium. If this can be proved feasible, the plates can be rolled and the screws die-machined, and vitallium will unquestionably occupy the position of the ideal metal for this purpose At the present time all three metals are acceptable.

The pioneer work in the development of the metal for use in plates and screws was done by Sherman of Pittsburgh. The rôle played by electrolytic action of metals in the tissues, and between different metals simultaneously employed, has been extensively investigated by Venable of San Antonio, who has developed the use of vitallium. Carnes of Massillon aided in the development of the so-called SMO steel (18 chrome and 8 nickel plus molybdenum). The Fracture Service of the Presbyterian Hospital in New York City has developed the use of the 19 chrome 9 nickel stainless steel.

The Sub-committee on Plates and Screws of the Committee on Fractures and Other Trauma of the American College of Surgeons has devoted a great deal of time and effort for some years to the problem. Exhaustive experimental and clinical investigations have recently been made by this Committee* under the auspices of the National Research Council and with the aid of Prof. Colin G. Fink in the Engineering Laboratories of Columbia University and of the Bureau of Standards. It is hoped that the whole matter of the metals used for plates and screws, and the methods of their manufacture and sale, can be satisfactorily standardized and that means can be found to enforce the standards, so that the surgeon

*Charles Venable of San Antonio, J. Huber Wagner of Pittsburgh, and Clay Ray Murray of New York City.

who buys plates and screws can feel completely safe in using them and need concern himself wholly with the proper way to use them. Any one who is going to do any considerable number of internal fixations should make himself thoroughly familiar with the details of plates and screws, should purchase them from reliable and trustworthy sources, and should be able by inspection to evaluate their worth.

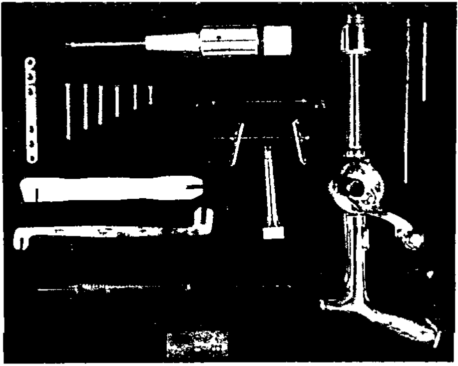


FIG. 546. Material used in internal fixation by plates and screws. Top center shows special screwdriver which holds screw rigidly fixed and prevents wobbling. Typical plate and screws are seen (see Fig. 547). In upper center are bolt assemblies and a nut tightener which slips over end of bolt. Upper bolt is used with a washer and a nut; lower bolt has a semicircular head and nut and is inserted through plates having a semicircular counter sinking of the center holes. Plate can be molded to shape of the bone and serves to distribute strain on bolt head and nut and so to prevent their cutting into the bone under stress. On right is a Lovejoy double gear drill *fitted with a Jacobs chuck and long and short drill points. Below plate and* screws are two forms of plate benders. Upper one is of aluminum and will not scratch plate. At bottom are shown a depth gauge for screws and a drill gauge to make sure that drill is of the right size for various screws. Wire on depth gauge has a slight hook at its end. It can be pushed through drill hole and then pulled back until hook catches on far cortex. Reading on scale will then designate length of screw to be used.

The following precepts should guide all internal fixation by plate and screws.

1. Use a plate of adequate length and strength. The length helps distribute strain. A rough guide as to length is the diameter of the bone at the fracture site. A length four times the diameter of the bone is desirable. A little longer is better than a little shorter. The thickness should vary with the heaviness of the bone being plated.

2. The screws fixing the plate should extend through both proximal and distal cortices of the bone. This helps in the rigidity of fixation.

3. Accuracy of reduction and accurate maintenance of reduction without shift during the application of the fixation helps insure rigidity. A wide variety of clamps as described under Open Reduction is of value here.

4. All screws should be placed at right angles to the plate surface. Otherwise, shearing strain tends to cause breakage or absorption about the screw.

5. All screws should be inserted through drill holes very slightly smaller in diameter than the shank of the screw without its threads if in dense cortical bone, and still slightly smaller if through thin cortexed cancellous bone such as is seen at the expanded bone ends and in overly decalcified bones. Larger drill holes result in inadequate threads, too small drill holes result in shearing strain on the screw which may cause it to break during insertion, or to develop weakness resulting in late breakage. Drill holes should be accurately centered to avoid abrasion of the screw threads and added strain during insertion.

6. Screws should be of the standard machine type, not of the tapering wood screw type.

7. Drills and screws should be carefully guarded against "wobbling" during insertion. Special screwdrivers and drills will aid in this. "Wobbling" leads to coning of the track of the screw with resultant poor threads and diminished holding power (Fig. 547).

8. The plate should be bent to conform to the shape of the bone surface to which it is applied. If the conformation to the bone surface is maintained only by the pressure of clamps during application, the resiliency of the plate will make it tend to spring back to its normal shape, and will impose additional strain on the screws when the clamps are removed. This may lead to breakage and to absorption about the screws.

The plate should be bent through an arc and not at an angle. This can be done by the use of a simple pair of plate-bending tools similar to a brace-bending tool (Fig. 546). This is best made of aluminum to avoid deep scratching of the plate. If made of hard metal, the jaws should be covered by pieces of thin rubber tubing. Heavy clamps, with the blades similarly protected, may be used if no plate-bending tool is available The bending pressure should be applied between, and not at, the screw holes in the plate.

9. The plate should be placed, whenever mechanically possible, on a bone surface covered by muscular tissue, and not on one covered merely by skin and subcutaneous tissue.

10. Plates having six or more holes for screws, three for each fragment, are to be used where possible. Those allowing of only a single screw in either one of the fragments can offer no hope of rigidity of fixation. Four screw plates, except in metacarpals, metatarsals, and phalanges may give rigid fixation, but usually do not allow of adequate distribution of strain.

11. Screws should be snugly set, but should not be forced beyond this point. If the setting of the screw is forced inordinately, undue strain is created which may later lead to breakage.

12. Cross fixation, as described below, by one or more screws in a plane at right angles to that of the plate screws, adds to the rigidity of the fixation by controlling torsional movement of the fragments, and at the same time cuts down the strain on the plate screws, minimizing the threat of breakage and of absorption about the plates and screws.

The general procedure can be described as follows:

The reduction having been accomplished and held by appropriate clamps, the optimum site for the application of the plate

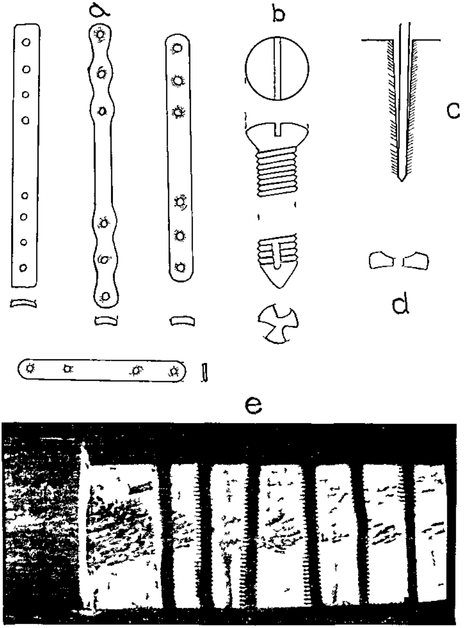


FIG 547 Details of plates and screws (a) Various types of plates Upper left does not have counter sunk holes Lower horizontal plate has a flat surface (b) Details of screw Slot in head must not be too deep Thread pitch may safely be anywhere from 22 to 32 to the inch Tap at lower end of screw must not be too long and in cross sect on should have right angled milled cutting edges as diagrammed (c) Effect of a wobbl ng drill or screw giving a funnel shaped hole and poor fixation (d) Cro s section of counter sinking of screw holes in plate Must not include more than half the thickness of the plate (e) Specimen showing the importance of proper dr ll holes and steadiness of screw and drill during insertion On left is shown poor threading by reason of too large a drill hole A 31 drill was used here instead of the standard 34 drill A 32 drill a 33 drill and a 34 drill were used in the succeeding three holes The next hole shows the effect of allowing drill or screw to wobble Poor threads with a hole of varying width Hole on extreme right shows effect of too small a drill hole A 36 drill was used and screw sheared off at point marked by threading If it had not sheared off the strain during insertion might have materially weakened it

from a mechanical standpoint is decided upon, preferably on a surface which will be covered by muscular tissue. The plate is then bent to conform to bone contours if necessary, placed in the desired position and held firmly in situ by an additional clamp or clamps.

The holes for placing the screws are now drilled, each screw being placed and set down before the hole for the next one is drilled. It is wise to place screws alternately in the two fragments. This helps guard against any loss of position during the application. It is helpful to know that a drill can be felt to bind just before it emerges from a cortex which it has transversed, and that a screw suddenly runs more freely under the same circumstances. The "feel" of this will help avoid sudden driving of the drill point into the tissues on the opposite side and will serve to check on the length of the screw used. It is wise to have a sterilized home-made gauge, consisting of a wooden or metal plate with a hole drilled through it by the proper drill, to check the diameter of the drill before using

The screws are inserted in the line of the drill holes. Steady, firm pressure is used while the screw is cutting the threads in the proximal cortex. Once that is accomplished, the screw runs through these threads with little or no resistance, until it meets the opposite cortex. Firm pressure is again needed to cut threads in the far cortex. As soon as the screw has done this, it again runs easily. It should protrude through the far cortex only by the length of its tap. A simple but accurate way of measuring the length desired for the screw is to mark the drill point by a clip or a clamp at the proximal cortex at the moment when it is felt first to bind, and then to go through the opposite cortex. If, as soon as the bind is felt, one drills slowly, the drill can be halted as soon as it suddenly ceases binding.

Another simple method is to use a wire with a sharp bend at its end, like a crochet hook, with a sliding sleeve about the wire. The wire is pushed through the drill hole, and then pulled back until the crochet hook catches on the far cortex. The sleeve is then slid down until it is in contact with the near cortex, and is fixed there with a set screw; the wire is withdrawn, giving the exact length desired.

All screws are so applied before any of the fixation clamps are removed. It is occasionally necessary to shift one of the clamps holding the plate in order to get at the holes in the plate. Before the clamp is shifted, another one is applied, which will take its place when it is removed.

The clamps holding the plate are then removed, the ones holding the fracture are held in situ A hole is then drilled on a plane at a right angle to the plane of the screws holding the plate, so as to go from one fragment, across the fracture line, and out through the other fragment. If the fracture line is oblique or spiral, this hole can be driven straight across the fracture line. If the fracture line is transverse, the drill hole has to be made obliquely across the fracture line from one fragment to the other, and counter-sinking for the screw head is indicated to avoid shearing strain. A screw is then inserted through this drill hole. This screw serves to take up torsional strain and eliminate torsional mobility at the fracture site, and to take this strain from the plate and its screws, thus distributing the strain. A second similar screw can be applied if necessary.

It should be here emphasized that the placing of this transfixion has proved, in our experience, to be a vital factor in securing rigidity of fixation and distribution of strain. With its use, the difficulties due to loosening of screws, breakage of materials, and reaction to the fixation metal have been reduced to a minimum, and visible absorption at the fracture site has been eliminated in clean cases. In our experience late absorption at the fracture site with a visible gap—so-called distraction—in the vast majority of cases results from only two causes:

(1) infection or (2) movement of the frag ments at the fracture site The latter is frequently present when a plate alone is used and may result in absorption The

The clamps are now removed and the fracture is tested for rigidity of fixation If an additional transfixion screw is needed it is applied

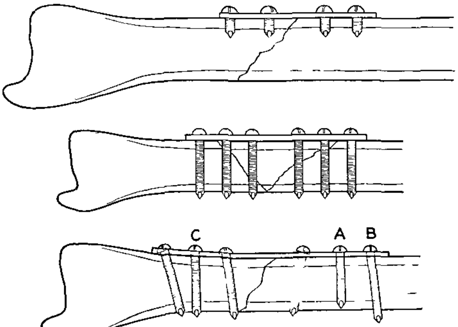


FIG 548 Common errors in plating technic

(*Top*) Short plate—increased strain on individual screws tending to produce absorp tion about them One cortex screws—added strain and a single *line* of fixation not extending through even a single plane No two plane or cross fixation Such fixation makes external immobilization of extremity mandatory resulting in prolongation of time required for bony healing and for functional rehabilitation Excessive strain on individual screws leads to bone absorption about them

(*Center*) Intermediate fragment Plate too short—excessive leverage with strain on screws Intermediate fragment not separately fastened Increased strain on screws Makes more difficult the accurate apposition of fragments and maintain ng of pos tion during drilling and insertion of screws One plane fixation—screws through both cortices accom plish plane fixation instead of linear fixation as by one cortex screws but must stand strain of torsion and shear in other planes External immobilization mandatory Risk of absorption about screws because of torsion and shear

(*Bottom*) Adequate plate length between four and five times diameter of bone Ade quate screw length gripping both cortices in all but screw A where tap only is in far cortex Screw B is too long and may irritate moving muscle or tendon Improper screw direction except for screws B and C which are at right angles to plate all screws are subjected to shearing No cross fixation at head end In addition screw abrades edge of screw hole and strips its own threads as it is forced in obliquely against edge of hole in plate External immobilization mandatory Risk of absorption about screws Risk of breakage of screws

cross fixation is our guarantee against this It is a most valuable and in our opinion, necessary feature of the fixation

The soft parts, with the attached and vas cular periosteum, are then placed back over the bone and the fracture site, and are

sutured with multiple, interrupted, fine silk. The towels are then removed from the skin edges. Fresh towels are placed about the described. The fracture is then accurately reduced, and the remaining portion of the plate can be used to maintain reduction

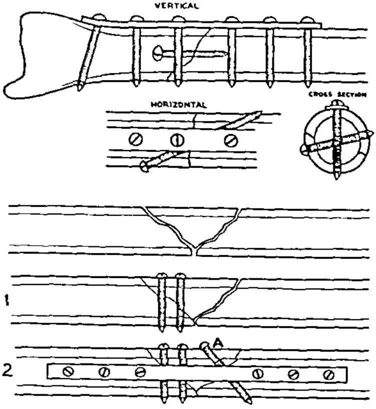


FIG. 549. Correct plating technic.

(*Top*) Plate adequate in length and molded to contour of bone. Screws adequate in number, grip both cortices, do not project unduly, and are at right angles to surface of plate. Cross-fixation by one or two screws in a plane more or less at right angles to plate screws. This takes up part of torsion and shear strain on plate screws, and minimizes risk of absorption about them. Such fixation will stand strain of postoperative functional activity in balanced suspension without other external support limiting joint activity. The result of such activity is more certain and more rapid bone healing, less residual soft-part pathology, and more rapid return of joint and muscle function.

(*Bottom*) Intermediate fragment. (1) First step is reconstruction with one or more screws into two fragments. This makes problem the ordinary one of fixing two fragments. (2) Rest of procedure is proper plating and cross-fixation of these two fragments using adequate length plate fixed by screws gripping both cortices and at right angles to surface of the plate, and screw A for cross-fixation. This method allows of more accurate reposition of fragments, less chance of slipping during fixation, and adequate distribution of bending, torsion, and shear strain. This minimizes chance of absorption about screws and allows of postoperative mobilization.

wound, and the skin is closed with interrupted fine silk or dermal sutures.

When difficulty is encountered in holding the fracture reduced—principally in transverse fractures—the position for the plate may be determined, and it may be fastened to one fragment by the technic previously through clamps fixing it to the other fragment while the remaining screws are applied. The cross fixation is then inserted.

When a loose fragment is present, it should be accurately reduced to one or the other of the main fragments and fastened by screws to assemble the bone into two

fragments These are then plated by the technic described and the intermediate fragment is then transfixed to the other main fragment

For proper and improper application of plates and screws see Figs 548 and 549

Throughout this procedure the technic previously described for open reduction should be carefully maintained

A great many minute details are here pre

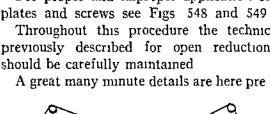


FIG 550 Postoperative immobilization *after rigid internal fixation for* fracture of leg A posterior molded plaster splint is applied up to knee Pearson leg piece is fastened at a fixed angle to Thomas splint by clamp and turnbuckle arrangement Leg is bandaged into splint and Pearson leg piece Thigh is bandaged into Thomas splint Posterior molded splint can later be removed and Pearson leg piece mobilized by overhead suspension and with leg bandaged into Pearson leg piece and thigh bandaged into Thomas splint mobilization of knee and ankle can be practiced

sented It is a mistake to assume that any of them is unimportant and unnecessary and not to be bothered with If the procedure appears too complicated or too difficult by reason of the many details to be observed then it is best not done Subtotal gastric resection and abdominoperineal resection of the large bowel depend no more on detailed and precise technic for their success than does the open reduction and plating of a recent fracture

Following closure of the wound the degree of postoperative external immobilization needed must be decided upon In all cases it is at least advisable to apply molded plaster splints until the patient is well out of the anesthetic and is quiet and rested Depending upon the rigidity of fixation obtained at operation upon the distribution of strain on the fixation obtained and upon the nature of the bone involved (dense and thick cortical decalcified and relatively soft cortical thin cortical cancellous etc) after 48 hours the decision must be made as to whether circular plaster molded plaster splints or suspension with or without traction is indicated The ideal is balanced suspension with mobilization of all joints *within pain and strain limits* One should approach this within the limits of safety What those limits are has to be based on *individual judgment in each case after* operation based on the factors cited above

It is a mistake to assume that movement of the part within the limits described is detrimental to wound healing This should be obvious if one remembers that the abdominal surgeon deals with wounds which are in the constantly moving abdominal wall Coughing sneezing or vomiting are a threat to his wound healing Breathing is not If the movements of the part are kept short of pain muscle spasm and strain the muscle action induced is beneficial to the minute circulatory drainage of the part and should help healing rather than hinder it as long as the wound is clean Once a wound is infected of course the situation is entirely different and absolute rest is indicated

Balanced suspension for postoperative mobilization after internal fixation is illustrated in Fig 550

To allow of it with profit and safety, the organization must be such that the apparatus can be inspected and checked (*Fig* 538) at frequent intervals during the day and that short periods of the prescribed mobilization exercises can be enforced at frequent intervals under adequate super

vision. Without the régime there is no profit and without the checking and supervision there is no safety.

EMERGENCY AND FIRST-AID TREATMENT

The proper emergency or first-aid treatment in fracture cases is a matter of considerable importance. It does much to minimize the amount of damage to important soft-part structures during the time lag between injury and definitive treatment, it very definitely lessens pain, and it diminishes the degree of shock by that means and by cutting down the amount of fluid, protein and blood loss into the tissues occasioned by the damaging and irritating movement of inadequately immobilized fracture fragments. It engenders greater ease and accuracy in the actual reduction of the fracture; it definitely aids in the promotion of conditions favorable for the healing of the bone lesion.

In compound fractures it plays an essential part in the minimizing of the dual risks of infection and delayed and nonunion.

The problem presented in the emergency handling of a simple fracture of a long bone is twofold: (1) Prevention or minimizing of shock, and (2) fixation of the fragments with the maintenance of as nearly normal length of the bone as possible until definitive treatment can be initiated.

When a complicating compound wound is present, a triad of additional problems is presented: (1) Prevention of further wound contamination, (2) prevention of wider dissemination of contamination already present, and (3) control of hemorrhage.

Hemorrhage is best controlled by a pressure pad rather than by tourniquet. The latter should never be used unless the former has failed. A pressure pad over a bleeding point controls hemorrhage but allows collateral circulation in the extremity. A tourniquet results in anoxemia of the whole extremity.

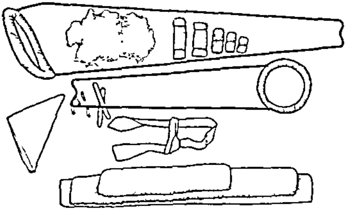


FIG. 551. Demonstrates simple equipment needed for adequate emergency traction splinting and ordinary splinting. Full-ring caliper can be replaced by a Keller-Blake half-ring splint. Hinged Murray-Jones arm splint, cotton for padding, bandage, tongue depressors and safety pins, a traction hitch and some padded basswood splints of various lengths are indicated.

Prompt and adequate immobilization minimizes pain, tissue damage, and shock, and helps prevent dissemination of contamination.

Protection of the wound by sterile dressing prevents further wound contamination. [For the rôle of chemotherapy see elsewhere in this chapter.]

The addition of traction to the immobili-

zation maintains the length of the bones and overcomes spasm and maintains muscle length during the wait for definitive treat ment

It is not amiss to make an earnest plea that every doctor carry with him in his car and keep in his office the upper and lower extremity traction splints and prepared and padded board splints of various sizes There is no expense involved—the splints are cheap and practically indestructible The apparatus is not cumbersome The applica tion of the traction splints is simple and easy In view of the value of adequate first aid splinting there is little excuse for failure to provide for it

Application of Emergency Traction Splints

For Lower Extremity Keller Blake Half ring or Thomas Full ring Splint

1 If not in that position already the patient is placed flat on his back while slow steady traction is made on the foot and the latter is slowly rotated into the neutral straight ahead position

2 While traction is maintained in this position a padding of cotton or any other material is gently wrapped about the ankle

3 Two strips of bandage or other mate rial are then tied about the ankle just snug about the padding—not tight One is tied with the knot on the inner side and one with the knot on the outer side

4 Manual traction on the foot is released after it has been replaced by traction on these strips

5 Keller Blake While traction is maintained the splint is slid under the side of the leg from the outer side the ring being snugged up under the tuberosity of the ischium posteriorly

Thomas The strips are passed through the ring of the splint and while traction is maintained on them the ring is pushed up along the leg and thigh until it comes to rest against the ischial tuberosity

6 The ends of the strips are passed over the distal end of the splint slowly pulled taut and tied

7 A tongue depressor lead pencil or similar object is passed between the two strips and is used as a windlass to twist them until under good tension It is then fastened to the bars of the splint

8 Four strips of bandage or other mate rial are then tied snugly about the splint and the contained extremity The sides of the splint prevent any constriction of the limb The strips are placed just above the ankle just below the knee just above the knee and at the hip

9 A support is placed beneath the tip of the splint From this time on the heel must be kept from resting on the ground bed stretcher etc If this is done the splint can be swung in any direction without disturb ing the fracture and without pain to the patient (Fig 552)

These splints can be appl ed over the clothing and without removing the shoe Clothing can later be removed by simply ripping along seams without disturbing the splint Wounds can be inspected without removing the splint

During transportation the splint can be suspended by its distal end from the roof of the car or ambulance

For Upper Extremity Murray Jones Hinged Arm Splint The application is exactly similar to that just described for the leg The initial traction is on the hand with the arm in slight abduction the fore arm in midrotation The padding is placed about the wrist The strips are tied snugly but not tightly on the radial and ulnar sides The strips are passed through the hinged ring of the splint with the bars in the vertical plane while traction is main tained and the ring pushed up along the arm until its upper border is over the top of the shoulder and its lower border in the axilla which has previously been padded The strips are pulled taut and tied about the distal end of the splint and the Spanish windlass traction applied Strips of bandage

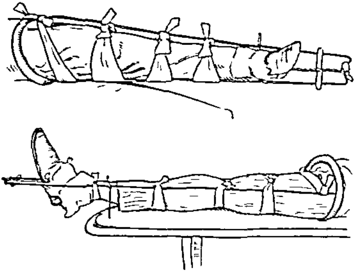


FIG. 552. Lower extremity emergency traction applied. (*Top*) Anteroposterior view. (*Bottom*) Lateral view. Splint is held off stretcher by a metal support. A pillow or a box under very end of splint would do. Heel and leg must not rest on anything. End of splint can be hung from roof of a car or ambulance.

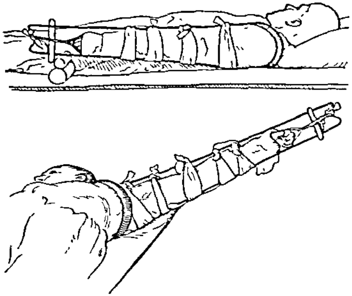


FIG. 553. Upper-extremity emergency traction applied. (*Top*) View with arm at side. Note that end of the splint is supported. It can be suspended from roof of a car or ambulance. (*Bottom*) Showing how arm can be brought out for purposes of x-ray, etc. This is made possible by hinging of ring.

are tied around the splint and the enclosed arm just above the wrist, just below the elbow, just above the elbow, and just below the axilla The splint is supported by some thing placed beneath its distal end or is suspended from overhead Because of the hinged ring the splint can be swung out to the side for purposes of x ray etc Clothing can be removed by ripping along seams without disturbing the splint, and wounds can be inspected without the necessity for its removal (Fig 553)

Numerous ingenious improvisations to substitute for these ringed splints have been devised Ski poles lengths of thin narrow board notched at either end rifles etc, have been used Fig 554 shows how a notched board can be utilized as a substitute

Splinting with Ordinary Board Splints or Substitutes Therefor

These splints partially fulfill the demands of emergency treatment, if properly applied but have definite disadvantages as compared with traction splints The immobilization secured is incomplete unless a risky degree of tightness in binding is secured No traction can be maintained, and the bones and muscles can, and do, shorten inside the splints Clothing cannot be removed and wounds cannot be inspected without removing the splints

When used, they should be well padded, and of adequate length They should be applied while slow steady traction is being maintained, in the hopes of holding some of the normal length in the event of overriding and to minimize the pain and damage caused by the moving about of bone fragments during their application Proper splinting of this type is shown in Fig 555

In compound fractures the wound should be covered by a sterile dressing It is not considered advisable to use wound antiseptics *For the use of bacteriostatics see* Chemotherapy elsewhere in this chapter A pressure pad should be added if bleeding is bothersome

The question is perennially raised as to whether a bone fragment which is protruding should be pulled back into the wound by the application of traction The consensus *is that it should, since the advan*tages of adequate immobilization and traction far outweigh, ordinarily, the obvious disadvantage of pulling the contaminated fragment back into the tissues It is essential, however, that the man who treats the case know that the fragment had been protruding when the case was first seen There are those who simultaneously hold that a protruding fragment should not be pulled back into the tissues by the application of traction but that if a fracture has been compounded from within (by protrusion of a bone end which has spontaneously withdrawn) it represents a relatively harmless form of compounding which needs minimal or no debridement It would seem far more logical to feel that there is no essential difference between compounding from within or from without in regard to *indications for treatment The latter is the* viewpoint espoused by the author

There are, naturally, a few commonsense exceptions to the general rule If a protruding bone fragment is grossly contaminated from a dangerous source it is wiser to forego the advantages of traction, and to splint it "as is" If a considerable number of hours are to elapse before adequate wound treatment can be accorded to the patient, it *might be conceivably wiser not to pull the* fragment back in by traction

Measures in Addition to Splinting

In addition to the splinting of the affected part, the use of morphine and sedatives, keeping the patient quiet and undisturbed, the administration of fluids by mouth, and protection against chilling are, of course, indicated

In cases of suspected intracranial or intra abdominal injury, morphine should be avoided, of course, and codeine or sedatives should be used instead

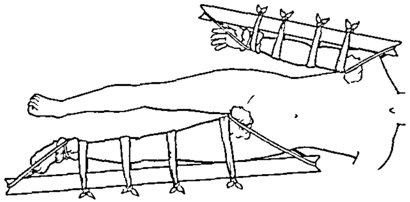


FIG. 554. Improvised traction with notched boards. Traction can be secured by increasing pull from ankle or wrist. Padding between board and extremity has been omitted in illustration.

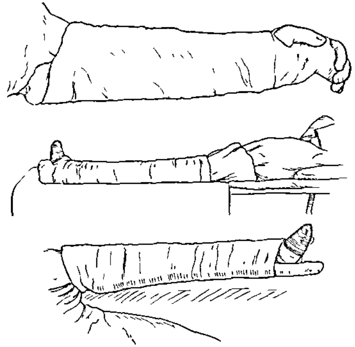


FIG. 555. Extent of splinting when basswood or other padded splints are used. (*Top*) Upper extremity. Splinting suitable for wrist or forearm. Note that elbow is included. If humerus is involved, splinted arm should be bandaged to side. (*Center* and *Bottom*) These represent lower-extremity splinting for foot and leg. If femur is involved, outer side splint should extend up to axilla and be bandaged to chest wall.

Spine Injuries The emergency handling and transportation of spine injuries is a matter of considerable importance An appreciable part of the neurologic damage suffered by these patients is the result of lack of wisdom or care during transportation and handling before the institution of definitive treatment The correct management of these cases is described in Chapter 26

TREATMENT OF SHOCK IN FRACTURE CASES

This is a major problem in the handling of many fracture cases particularly in severe compound fractures where marked blood loss may be an obvious complicating factor The fact that the actual blood loss into the tissues may be extreme in multiple simple fractures or in single fractures with marked soft part damage beneath the skin is frequently overlooked It has unfortunately been a dictum in the past that in fracture cases in severe shock nothing definitive should be done about the fracture until the patient is out of shock Except in the actually moribund case this is a faulty and harmful concept of the problem Definitive treatment of the fracture in these cases should be concomitant with and considered a part of the treatment of the shock In compound fractures the primary soft part wound is part of the fracture picture and its adequate treatment is as essential to satisfactory handling of the shock problem as is the handling of the bone wound

The factors involved in the shock of the fracture case are (1) Blood loss—open or into the tissue (2) fluid electrolyte and protein loss into the damaged tissue (3) toxemia due to absorption of autolyzed products of tissue death and tissue hemorrhage and (4) a neurogenic factor due to pain

It is important to realize that shock may be impending and imminent before the clinical picture is present and that severe and continuing blood loss may be obscured by the clinical picture of shock The classic clinical picture of shock and hemorrhage will not be discussed here

It is also to be remembered that the picture of shock does not automatically indicate the treatment indicated for the individual case Unquestionably a certain number of patients each year are harmed by the routine use of saline or saline and glucose alone as well as by the use of other media without the aid of saline or saline and glucose The clinical picture calls for the treatment of shock But the onset of shock may be anticipated by the use of adequate criteria and the exact indications for preventing its onset for treating it when present and for minimizing the chances of secondary and delayed shock can be furnished by the use of these criteria

What criteria have we then whereby we can determine the imminence of the clinical picture of shock adequately prevent its appearance or adequately treat it if the condition is already present?

The criteria apart from the clinical picture are (1) Hematocrit level (cell volume of venous blood) (2) whole blood specific gravity (3) plasma specific gravity and (4) plasma protein level

These criteria enable one to establish the presence and relative amounts of fluid and protein loss in the circulating blood to detect the presence of concomitant severe hemorrhage with red cell loss to recognize the approach of edema level in the serum proteins and to recognize dehydration in the presence of anemia This knowledge indicates directly what should be done to prevent the occurrence of shock and to combat it when it occurs

1 Hematocrit Determination (1) Use a sterile and completely dry syringe After getting the needle into the vein remove the tourniquet and wait a minute or so before withdrawing the blood avoiding air bubbles (2) Introduce 5 to 6 cc of blood so withdrawn into a Sanford Magath hematocrit tube containing heparin (One mg

of the powdered sodium salt as prepared in the Connaught Laboratories of Toronto University is adequate.) (3) Invert the tube two or three times to mix the blood and the anticoagulant. (4) Cork it airtight with a rubber stopper and spin in a centrifuge at 2,500 revolutions per minute for 15 minutes. (5) At the end of that time the height of the total sample divided into the height of the centrifuged cell portion of the sample will give the volume of the cells in relation to the total volume of the sample in per cent. This is the hematocrit. The average male figure is 46; the average female figure is 41.

2. **Blood Specific Gravity.** This is determined by the falling-drop method devised by Barbour and Hamilton. By means of a simple set-up of apparatus the falling time of a drop of the patient's blood (secured by a finger prick) between two set marks 30 cm. apart in a tube containing a standard bromobenzene-xylene mixture is compared with the falling time in the same mixture of a drop of standard concentration of potassium-sulfate solution of known specific gravity. The timing is done with a stop-watch. Standard corrections are made for temperature. By using a simple calculating scale furnished with the apparatus, the apparent difference in density between the standard and the bromobenzene-xylene mixture and that between the blood drop and the mixture is easily obtained. If the blood drop falling time is slower than that of the standard, the difference is subtracted from the specific gravity of the standard to give that of the blood. If the blood drop falls the faster of the two, the difference is added to the specific gravity of the standard to give that of the blood. The procedure takes about two minutes or so, and is quite simple. The normal average male value is 1.0566 and the female 1.0533.

3. **Plasma Specific Gravity.** This is determined for plasma in quite a similar manner to the preceding, but using a different Standard Solution. Plasma completely free from protein has a specific gravity of 1.00687. Each increase of 0.0001 in the specific gravity from this point indicates 0.03 Gm. per cent increase in plasma protein. The average normal figure is 1.0267.

4. **Plasma Protein Content in Grams Per Cent.** This is easily determined from a prepared chart of comparative values based on the preceding determination. The values run from a plasma specific gravity of 1.0187 indicating a protein of 4.01 Gm. per cent to a specific gravity of 1 0348 indicating a protein of 9 49 Gm. per cent. The average normal value is 7 0 Gm. per cent.

It is obvious that, with some relatively simple apparatus and some prepared tables, the technic is neither involved nor time-consuming

In simple dehydration in shock uncomplicated by hemorrhage there are found comparably increased values for hematocrit, blood specific gravity, plasma specific gravity, and plasma protein. Rational treatment involves the use of hypertonic saline, or saline plus hypertonic glucose, to relieve arteriolar spasm, to decrease the viscosity of the blood, and to aid in bringing about the return of fluid from the tissues into the circulation Eschatin may be used in the infusion to aid in restoring capillary tone and blood pressure in the event of failure of prompt response to the hypertonic solution. Transfusions are given as and if indicated by later studies.

In shock complicated by hemorrhage, obvious or concealed, the values for hematocrit and blood specific gravity fall while the values for plasma specific gravity and plasma protein remain relatively unchanged. The indications are definitely for restoration of blood volume by transfusions.

In dehydration in shock complicated by inordinate protein loss, as evidenced by increased hematocrit and blood specific gravity in conjunction with lowered values for plasma specific gravity and plasma proteins (characteristic of burns and frequent in severe crushing injuries) plasma is indi-

cated in addition to the fluid replacement by saline and glucose If plasma proteins fall to or below about 5 Gm per cent an edema level is reached, at which intravenous fluids such as saline when given alone merely leak rapidly into the tissues materially worsening the patient s general and local condition

These changes precede the onset of clinical symptoms, allowing and indicating the treatment necessary to forestall the occurrence of shock, and are an excellent indication of response or failure to respond to therapy considerably before the clinical picture will give such indication

Definite response to therapy as indicated by these criteria allows operation or fracture reduction to proceed while the therapy is continued even though the patient still presents the clinical picture of shock The reduction and immobilization of the fracture, and the removal of dead and devitalized tissue and collected hemorrhage and exudate in compound fractures definitely eliminate primary factors in the etiology of the shock picture, and the patient leaves the operating or emergency room in better shape than he entered it, and without having to face the need of surgery or manipulation at a later and less advantageous time with a further risk of shock The later reduction is apt to be more traumatizing more difficult, and less accurate, and adequate treatment of a compounding wound may have been seriously compromised by the delay occasioned in attempting to bring the patient completely out of the clinical picture of shock while factors involved in the cause of the condition are still operative

It is of course, taken for granted that the intelligent use of morphine, quiet, protection against chilling and the adequate mouth administration of fluids (when possible) are used concomitantly with the therapy already described

When blood or plasma are indicated but are not immediately available, saline and glucose may be used temporarily to provide blood volume until the former can be secured

The rôle of eschatin has already been indicated

The author feels that the importance of this method of handling the shock incidental to injury cannot be too strongly emphasized as leading to more successful shock therapy and to sounder and better treatment of the injury itself

COMPOUND FRACTURES

The general principles underlying the handling of compound fractures are discussed in the succeeding chapter It is essential that the lesion be regarded as a wound involving both bone and soft parts these must always be considered together and not regarded as separate treatment problems The single problem presents itself briefly in three phases (1) Prophylaxis against the translation from a state of contamination into that of clinical infection, (2) the minimizing of damage caused by any infection which may occur, and (3) healing of the damaged tissues in as short a time as possible with minimal residual disability and deformity

In meeting this problem the following factors are of prime importance (1) First aid or emergency treatment (2) time lapse between first aid and definitive wound treatment, (3) definitive wound treatment in the stage of contamination, bone and soft parts, (4) definitive wound treatment in the stage of infection, bone and soft parts, and (5) late reconstruction and rehabilitation procedures

1 **First Aid or Emergency Treatment** This first factor is discussed in this chapter under the heading First Aid and Emergency Treatment, q v

2 **Time Lapse Between First Aid and Definitive Wound Treatment** This second factor is a most important one Military experience in the present conflict has served to intensify its importance more and more

in relation to prophylaxis against the translation from wound contamination to wound infection and in relation to the minimizing of the damage caused by any infection which may develop. Indeed, it is difficult to evaluate adequately the relative importance of this factor and that of chemotherapy in its various forms in this respect. The radical cutting down in general of this time-lapse element, improvement in the provision of skilled and trained personnel in advanced areas for early definitive treatment, provision for early and adequate blood-replacement facilities, and the use of chemotherapy have all been concomitant developments. Hasty and too superficial attempts at evaluation of the relative importance of these various factors may be, and have been, not only erroneous but also damaging in practice.

It must be generally agreed, the author believes, that the lapse between the time of occurrence of a compound injury and the time of definitive wound treatment, viewing the bone and the soft structures as parts of the same wound, is a factor of prime importance. The discussion of this factor in relation to the use of chemotherapy is continued under the heading Chemotherapy farther on in this chapter, but it can here be stated that every effort should be made to keep this time lapse at a minimum. This is of prime importance again in relation to the treatment of shock in compound fractures. Undue, unnecessary, and unjustified prolongation of this time lapse by the method of handling the shock problem is common. It is discussed under the heading of Treatment of Shock in Fracture Cases elsewhere in this chapter.

3. Definitive Wound Treatment in Stage of Contamination, Bone and Soft Parts. This third factor is one of extreme importance, and emphasizes the futility of attempts to lay down rules of thumb to be routinely followed. In this connection it is essential that one must keep in mind the radical and basic differences which exist between civil surgery and military surgery. In civil surgery the doctor's primary and sole consideration is the individual under treatment. In military surgery, on the other hand, even though every attempt be made to do the best possible for the individual, what can be done is variously limited by the press of time and the number of wounded to be cared for, by the phase of battle during which treatment is rendered (advance—static—retreat), by time lapse and transportation difficulties, by equipment and personnel shortages or necessary limitations, and by the enforced use of personnel of widely differing capabilities and training background. The net result of this situation is that it frequently becomes *necessary*, with individual exceptions, of course, to issue directives (rules of thumb) for the handling of various situations in the manner calculated, on the basis of experience, to produce the least risk of harmful sequelae to the greatest number of wounded.

Let us illustrate the point by a specific example. In general it has become a front-line regulation that no compound fracture wounds shall have primary closure. No one can deny the potential value of primary closure if it can be safely done and if the patient can be under careful and continuous observation during the period of wound healing. It decreases the chances of secondary infection, minimizes scarring and wound-healing time, adds to the chances of successful healing of the bone portion of the wound, and minimizes in extensive wounds continuous fluid and protein loss to the patient.

In civil practice all the various factors discussed below under wound treatment can and must be evaluated in terms of the individual patient. Some wounds are closed, some are partially closed, some are left wide open, some are subjected to delayed closure on the basis of this evaluation. In military practice *all* these wounds are left open, and only delayed closure is considered because it has been recognized that, under the con-

ditions cited, it is impossible to adequately evaluate and cover the whole situation in the individual case, and that the *safest* thing to do is to leave all wounds primarily open

There is no question but that in certain hands and under certain conditions many of these wounds could be primarily partly or completely closed successfully with material benefit to the individual patient As soon as individual judgment is allowed, however, it becomes practically impossible to limit the exercise of it to those qualified, and to situations justifying it The procedure is adopted therefore, which is safest for the majority, although not necessarily best for the individual And it is an excellent viewpoint in consideration of the conditions which exist

The same is true in regard to the *primary* use of internal fixation in early cases, and in regard to the growing antipathy in both Army and Navy medical circles to the *primary* use of pin fixation by apparatus or even combined with plaster These methods in proper hands in suitable cases and under favorable conditions in civil life are excellent means of carrying out general principles Under military conditions during battle they ordinarily entail entirely too much risk to be justifiable as primary procedures As secondary procedures, after the case has been removed to a surgical environment approximating that of civil life, they may be logically and intelligently employed

Definitive Wound Treatment in Stage of Contamination in Civil Practice The stage of contamination is that in which the contaminating organisms lie at or near the surfaces of the wound Invasion of the tissues surrounding the wound has been minimal and inflammatory reaction is limited to that secondary to the trauma itself Trying to answer the question as to how many hours after injury this status may be expected to continue before the stage of infection supervenes is a good deal like trying to answer the question "How long is a piece of string?"

In civil life the evaluation necessary to meet this problem is based on the answers to a number of questions How extensive and severe is the skin wound *and the underlying tissue damage?* How gross and of what character is the contamination? What has been the emergency and first aid treatment in the interval that has elapsed since injury? If the skin wound is small and the damage to underlying soft parts slight if the patient is cleanly and his clothes are clean, if the gross contamination is slight or nil and has been sustained from a clean roadway or in a clean car mill or factory and if adequate emergency splinting of the fracture and protection of the wound have been in effect since the time of injury, treatment based on a contaminated stage may be a valid procedure up to 16 or more hours after injury If the tissue damage is extensive, the patient and his clothes dirty, the contamination grossly visible and sustained in a barnyard or a dirty tenement apartment or shack and if wound protection and splintage have been faulty and inadequate, treatment must be based on the assumption of an infected state after six to eight hours Between these two extremes the status of the wound must be judged on the basis of an evaluation of all factors for the individual case

Wound treatment of compound fractures in the contaminated stage in civil practice involves the following steps (1) Preparation, (2) wound toilet or debridement, (3) fracture reduction, (4) closure (5) fracture fixation, and (6) prophylaxis against tissue tension, against secondary wound contamination or irritation and against the development of anaerobic organisms which may be present in the wound

Preparation This is accomplished by thoroughly blocking the skin opening with sterile gauze, and cleansing the intact skin as for a surgical operation Shaving of the skin, followed by the generous use of soap and water, alcohol, and then ether is a thoroughly adequate routine When the skin

is grossly dirtied by grease or oil, benzene as a preliminary is effective in removing it The area prepared should be extensive—the whole lower leg for wounds of the leg; the whole foot, ankle, and lower half of the leg for ankle wounds; the whole thigh for thigh wounds; the lower half of the thigh and upper half of the leg for knee wounds, etc.

Clean skin is a major safeguard against secondary infection during the healing period. The cleansing should be done with sterile gauze or cotton pads, and not with a scrubbing brush. Time and the generous use of the various solutions are to be preferred to vigorous energy in scrubbing to effect thorough cleansing. The idea is to clean the skin without damaging or irritating it.

When the skin has been thoroughly cleaned, the prepared area may be covered by a skin antiseptic if so desired, provided it be thoroughly nonirritating. The author does not believe this to be necessary, and, if the solution is at all irritating, believes it to be harmful in many cases. There are many, however, who do not hold this viewpoint, and who prefer the use of skin antiseptics. The author is firmly convinced that where the skin antiseptics are used, they should be used in addition to, and not in place of, the thorough mechanical cleansing of the skin. If this is the practice, there can certainly be no objection to the use of nonirritating skin antiseptics.

The gauze plug is then removed from the wound, and the part is grossly draped, leaving the wound and a moderately generous portion of the surrounding skin exposed, so that any necessary enlargement of the skin opening may be done.

The author does not believe that scrubbing of the wound or lavage of it at this time is sound practice. The wound contamination should be removed with the dead and devitalized tissue which it contaminates as part of the so-called débridement described below. Scrubbing or lavage of the wound from the outside at this stage serves to possibly disseminate contamination in the wound, and certainly tends to recontaminate the surrounding skin which has just been so carefully cleansed. Many others advocate wound scrubbing or lavage at this point, the writer takes definite exception to the practice as illogical and as a violation of principle.

Undue damage to the tissues and further dissemination of contamination in the wound take place unless the part is carefully handled during this cleansing procedure. Steadying traction should be maintained, whether manually or by apparatus, and any necessary movements of the limb under traction should be gently and carefully carried out with this idea in mind. The value of early and adequate emergency splinting to prevent tissue damage and spread of contamination is often largely lost through careless or thoughtless handling of the part during this stage of definitive treatment. It is the writer's custom to have an assistant maintain moderate traction on the limb until wound treatment has been completed and reduction of the fracture has been attained.

Débridement. This term is used with full understanding of the fact that it does not embrace by strict definition the procedures outlined. It is, however, the term in popular use to describe the wound toilet which modern surgical principles call for. It makes little difference, after all, except academically, what label is attached to the procedure if it is properly carried out. Emphasis should be laid on what to do and why, rather than on what to call the procedure. The term will therefore be used throughout this discussion to include the sum total of procedures used in the cleansing of the compound wound in its early or contaminated stage as previously defined.

The procedure is done with these purposes in mind: (1) Removal of all gross contamination, including contaminating foreign bodies. (2) Removal of all dead and devitalized tissue. If left, it serves as pabu-

lum for the bacteria which still remain despite the most adequate of wound toilets (3) Elimination of dead spaces (4) Careful and thorough hemostasis to prevent subsequent hematomata (5) Preservation of all viable and uncontaminated tissue (6) The infliction of as little additional damage to sound tissue as possible (7) Avoidance of additional contamination or further dissemination of the original contamination

In order to carry out these purposes the procedure should be performed as follows The skin having been prepared and the part draped the edge of the skin wound is excised It is essential that all possible skin be preserved Even an obviously avascular skin flap if it be untraumatized and free from contamination ground into its substance, may serve as a primary skin graft for coverage if its subcutaneous tissue is removed and a pressure dressing is applied The ideal is to excise only one eighth to one quarter of an inch of skin circumferentially from the wound

All removal of tissue during the debridement should be done with a sharp scalpel and a thumb forceps Scissors should not be used as they are crushing instruments rather than cutting ones

When the skin edge, together with such skin as is badly contused or grossly contaminated, has been removed the instruments should be either discarded for a new set, or should be thoroughly cleaned before proceeding

The next step is to enlarge the wound preferably in the longitudinal axis, from either end so as to completely expose the extent of damaged tissue beneath Towels should then be clipped to the edges of the enlarged wound to exclude skin surface as completely as possible

The subcutaneous tissue is then debrided circumferentially removing all dead and devitalized or grossly contaminated tissue, including that on any obviously avascular skin flaps which are otherwise clean and undamaged *The scalpel and thumb forceps* used are then discarded or thoroughly cleansed

With new or cleansed instruments the fascial layer, the muscle planes and finally the bone and periosteal planes are successively subjected to circumferential removal of dead obviously devitalized or grossly contaminated tissue During the procedure all pockets or potential dead spaces are eliminated Hemostasis should be as thorough as possible using the smallest clamps available and the finest plain gut ligatures or the minimal application of the cautery current Silk or cotton should not be used The tissues should be handled as gently as possible throughout the procedure

Opinions differ as to the wisdom of primary suture of severed nerves and tendons The author s preference is to employ primary suture with fine gut unless he feels that the wound will probably not remain clean In the latter event the tendon or nerve ends are tacked to the surrounding tissues by a single suture of fine gut through either edge to keep them closely approximated until delayed or secondary repair can be undertaken Such wounds in which infection is viewed as probable should not be subjected to primary closure in his opinion

If primary repair of nerves or tendons is done, it should be done after lavage of the wound as described below

Thorough exposure and debridement of the wound layer by layer having been accomplished a soft rubber catheter is *introduced into the depths of the wound, and* through it, from the depths outward lavage of the wound is carried out with saline, the container being elevated sufficiently to make the flow forceful and vigorous This technic for the lavage is important If saline is merely dribbled into the wound from without inward or if the flow is so gentle that it lakes in the wound the so called lavage may do harm rather than good by disseminating contamination from the superficial areas to the deeper levels If *properly carried out it washes contamina*

tion out from the wound. Metaphorically, we wish to avoid a tub bath of the wound whereby every part of it is exposed to the contamination washed from every other part; what we desire is a shower bath which carries the contamination outward away from the wound surface. The lavage should be thorough, depending upon the size of the wound; several liters of fluid may be required. In this connection the use of the lavage pan devised by Henry Marble, and described in Chapter 37, is very helpful.

Reduction. Following the lavage, the fracture should be reduced by either open or closed manipulations or both, before the question of closure of the soft parts is considered. The reduction of the fracture is, in essence, the closure of the bone portion of the wound. If internal fixation is to be used, it is now applied in accordance with the proper technic for such procedure (see Maintenance of Reduction and Immobilization by Internal Fixation elsewhere in this chapter). A second lavage of the depths of the wound following the reduction (and internal fixation, if done) is wise.

For discussion of the use of chemotherapy in compound fractures see elsewhere in this chapter.

Closure. The question of wound closure now comes up for consideration. This is, and has been for many years, a moot point. A closed wound is a definite advantage in that it minimizes the chances of secondary contamination, it aids the fracture healing by providing vascular soft parts to cover the fracture site, and simplifies the subsequent treatment of the case as a whole. A primary closure entails the threat of tissue necrosis and infection if the closure is under tension, of increased chance of infection if it allows the development of tension from within by reason of contained edema or exudation, or of hematoma development resulting in dead space, or if it seals in appreciable amounts of dead tissue or contamination. The risk of closure ordinarily increases directly with the time lag between injury and wound treatment and inversely with the adequacy of the first-aid or emergency treatment accorded wound and fracture.

It is considered safe to close a compound wound in the contaminated stage (1) if, after débridement, there are not left appreciable amounts of dead and devitalized tissue and contamination, (2) if the suture is not under appreciable tension, (3) if subsequent dead space and hematoma formation can be prevented, and (4) if excessive tension within the tissues themselves caused by subsequent edema and inflammatory exudate can be prevented. Evaluated from this standpoint a wound may be closed, partly closed, or left open.

Under no circumstances should a wound be closed with the insertion of drainage.

Deep sutures should not be used.

Closure should be limited to skin and subcutaneous tissues.

When such closure seems impossible without the risk of tension, releasing incisions which allow of bone, tendon, and other vital structure coverage at the expense of exposure of undamaged muscular tissue may be used.

The areas so exposed may be immediately or subsequently grafted by the dermatome or Thiersch or pinch grafts.

A primary-flap graft may be used in a more than usually clean wound. This is of particular value in hand wounds to secure coverage of tendons.

When releasing incisions are made, care must be taken not to make the skin bridge so created too narrow, and the direction of the incision must be such as to minimize the risk of circulatory embarrassment. Incision in the long axis of the limb is therefore preferred, and incision in the transverse axis must be practiced with due caution and consideration.

Methods of accomplishing partial or complete closure without tension in these wounds are illustrated in Fig. 556.

Methods of dealing with the wound left

unsutured when closure is deemed dangerous or inadvisable are discussed below

Following partial or complete closure of the soft part wound and reduction of the fracture (closure of the bone wound) a pres

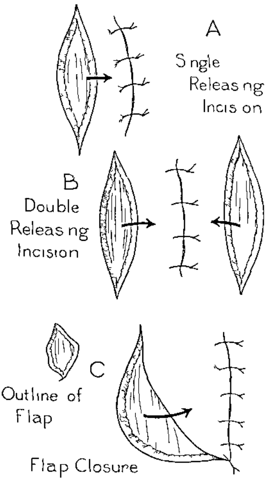


FIG 556 Methods of obtaining closure in compound wounds (A) Single releasing incision (B) double releasing incision (C) flap closure

sure dressing is applied to eliminate the risk of dead space hematoma formation and the creation of tension within the tissues by edema or inflammatory exudate A word about pressure dressings is worth while The purpose of their use is clear enough but as applied they often either do not fulfill their purpose or else go so far beyond it as to do actual harm

Sharply localized pressure is not desired Extensive and moderate pressure is called for

Actual compression of the tissues should be sufficient only to eliminate dead space Otherwise the dressing should serve only to prevent distention of the normal tissue spaces from within It cannot obliterate by excessive pressure the tissue space and the lymphatic and ultimate capillary circulation without doing harm

So called skin tight unpadded circular plaster is used by some men for this purpose If properly applied and if accorded proper after treatment under adequate observation it carries out its purpose well See the discussion of the use of plaster in another part of this chapter for details of the method It might be well to emphasize the fact that skin tight is an unfortunate and misleading designation Form fitting or snugly molded would be better terms No plaster encasement or other splint should be tight

Others use cotton wadding gauze fluff or mechanics waste compressed by elastic bandages of the Ace or other types or gauze rolls with or without sea sponge over the wound and/or grafted areas covered by snugly molded circular plaster The pressure dressing beneath the plaster should be extensive For a compound fracture of both bones of the leg for example it should extend at least from the bases of the toes to the knee

The author s preference is for snugly molded plaster splints over the pressure dressing to be replaced by form fitting circular plaster without pressure dressing after wound healing has been secured and any inflammatory swelling has been largely dissipated

The patient should be watched carefully for (1) General signs of infection (2) local symptoms suggesting infection and (3) adequacy of circulation in the exposed portion of the extremity—toes and fingers

In the presence of a pressure dressing

extreme elevation of the part should be avoided.

Treatment of Wounds Not Primarily Completely or Partially Closed. When, for any of the reasons already adduced, it is considered inadvisable to attempt closure, and the wound is left open, several courses may be followed.

The wound may be packed open. The term is unfortunate. The idea is to loosely fill all the crevices and recesses, and to keep the margins of the wound well separated so that it is coned from without inward. The purpose is to allow the escape of all exudate, edema, and products of tissue autolysis, to prevent fluid-filled dead space, to avoid all intra-tissue tension, and to insure healing from the depths toward the surface. Packing implies tight filling of the wound, which is not desirable since it tends to cork the wound, and so to defeat the purpose of the procedure.

Petrolatum gauze is commonly used for this purpose. If it is used, it should be petrolatum-*impregnated* gauze and not petrolatum-*smeared* gauze. Excess petrolatum is not an advantage. The skin about the wound should not be covered with petrolatum gauze, as it then tends to macerate, and to secondarily contaminate the wound.

In place of petrolatum gauze, xeroform gauze may be used, and is preferred by many. Xeroform gauze is gauze impregnated with a mixture consisting of 95 per cent petrolatum plus xeroform (a bismuth compound), paraffin, and beeswax.

In place of either of the above, plain gauze may be used. It is the author's personal preference. It has been advocated by Trueta, and has come to be preferred in many theaters in World War II.

Gurd of Montreal employs a form of wound filling which he calls curtain drainage, employing gauze impregnated with a paste containing bismuth, iodoform, and petrolatum designated as BIPP, the wound surfaces being covered by a thin layer of the medicament itself before the gauze-impregnated filling is inserted. It has a certain amount of antiseptic power, and it is claimed that the method minimizes the chance of corking effect. It also cuts down the element of unpleasant odor. The bismuth and iodoform in susceptible individuals may have some toxic effect if the area is large, and this must be watched for. The method has been used very successfully in Canada and in England, but has not been extensively employed in this country. To carry out its purpose the dressing must be unusually careful and detailed. This may be one reason why it has not been more universally used. One of the reasons why the open-wound treatment of compound fractures by the "packing" method in general frequently fails to adequately carry out its purpose is failure to exercise sufficient care in the details of the dressing.

A pressure dressing, as previously described, is applied after the insertion of any of these wound fillings. If plaster immobilization is used it is then put on.

Wound dressing is done at as infrequent intervals as possible dependent upon the general condition and local symptoms of the patient, the amount of discharge, the odor present, and the condition of the plaster.

Late skin grafting for granulating areas may be indicated.

Delayed or secondary closure may be done, with or without the aid of chemotherapy (see elsewhere in this chapter) when indicated in a wound which is clinically clean and healthy and bacteriologically safe. The former is the more weighty consideration. All the precautions used in primary closure should be observed in delayed or secondary closure.

As advocated by Sherman and Wagner, those wounds left open may be treated by the use of hychlorite solution after the well-known Carrel technic with or without delayed or secondary closure as indicated. The solution used, in preference to Dakin's solution, is used because of its stability,

minimizing the risk of excess acidity with its possible decalcifying action and wound irritation This method requires careful dressing technic and frequent dressings which may be one reason why it is not more extensively used Properly carried out it gives excellent results

A variation of open wound treatment which is preferred by the author is the primary insertion of through and through sutures from within outward (using a separate needle on each end of the suture) which are left untied The wound is then treated by any of the methods cited At the end of six to ten days (preferably six) if inspection reveals a clinically clean nonedematous wound the wound filling is removed and the sutures are tied to draw the wound surfaces as close together as possible *without creating tension* This often allows a partial or complete delayed closure without the need of additional surgery

4 **Primary Treatment of Compound Wounds in Infected Stage** If it is felt that a compound wound when first seen has passed the stage of contamination and must be considered as already infected debridement as described heretofore should not be practiced The skin preparation and draping should be carried out as described Following this the edge of the skin wound should be excised and the wound should be extended to the limits of the underlying tissue damage The fascia should be split to expose underlying tissue sufficiently to allow unroofing of all recesses gross surface contamination and foreign bodies should be removed and dead surface tags snipped off A lavage of the resultant wound from within outward should be done to aid in the removal of gross surface contamination No primary closure should be considered If free and adequate drainage is not secured by this simplified procedure counter drainage wounds should be made Wound treatment as previously described should then be carried out and secondary closure or, in some selected and specially favorable cases delayed closure may be performed as indicated

USE OF CHEMOTHERAPY

It is important that it be fully realized that chemotherapy whether systemic or local with either the sulfa group of drugs or penicillin is not a substitute for sound surgical principles and practice Its use does not warrant any alteration in the procedures prescribed in the discussion of compound fractures It should be used as an adjuvant to the procedures of sound practice within expectations as outlined below The details of a good surgical technic in clean cases cannot be relaxed because of the concomitant use of chemotherapy in the wound

There has developed a tendency on the part of many surgeons to substitute chemotherapy for sound principles and good technic On the basis of the known careful and controlled investigations of the action of chemotherapeutic bacteriostatic agents of the sulfa group and of penicillin at the present writing the following statements must be accepted as valid They are not based on impressions on cases treated without controls or on results on cases which lack an adequate follow up Many of the reports from military sources are deficient in one or more of these respects The statements here expressed are based on evaluations not open to that objection

1 There is no valid evidence to show that either the systemic or local prophylactic use of chemotherapy cuts down the morbidity to local infection in compound wounds Local calcium penicillin thiazole may be an exception to this statement (see discussion below)

2 There is valid evidence tending to show that the systemic and local use of chemotherapy may cut down the incidence of systemic infection from compound wounds and may limit the local extent and spread of infection when it does develop

3. There is no question but that the systemic use of chemotherapy has a marked effect on established systemic infection.

4. There is no question but that the systemic use of chemotherapy has a definite effect on established tissue infection when that infection is in a spreading, not walled-off, stage.

5. There is no question but that the systemic use of chemotherapy has a minimal effect on established tissue infection once the latter has become well localized and walled off.

6. Local chemotherapy frequently has definitely beneficial effects in the localized and walled-off established tissue infection, when coupled with sound surgical care. It is not a substitute for such care.

7. Sulfa-drug therapy is more effective against the streptococcus than against the staphylococcus. Many strains of staphylococcus are sulfa resistant. Penicillin is apparently equally effective against both groups. There are strains of both groups, however, which are penicillin resistant. Penicillin is ineffective against the gram-negative bacilli (colon bacillus [*Escherichia coli*], *Bacillus proteus, Bacillus pyocyaneus*).

8. There is evidence suggesting that in the case of organisms resistant to either penicillin or the sulfa drugs the combined use of both drugs may be effective.

9. There is evidence to show that inadequate systemic dosage may result in the acquiring of resistance by organisms originally sensitive to either drug.

10. Dead and devitalized tissue in a wound treated by chemotherapy tends to prevent the desired bacteriostatic action. This seems to be more marked in the case of the sulfa drugs than with penicillin. Extravasated blood, hematomata, and collections of pus and exudate have the same effect. This may be one of the reasons for the apparent ineffectiveness of chemotherapy as a prophylactic agent against infection in compound fractures.

11. The local use of chemotherapy in clean operative wounds as a prophylactic against infection seems to have value. This may be due at least partially to the absence of any large amount of dead and devitalized tissue, extravasated blood, or collections of exudate in such wounds.

12. Against the anaerobic gas infections, the best results seem to be attained in those cases treated early by the combined use of adequate amounts of penicillin and serum, plus proper surgery (see Gas-Bacillus Infections, below).

13. When used locally the sulfa drugs do not constitute a handicap to wound healing unless used in excessive amounts. The dumping of large amounts of the powdered drug into a wound does constitute a hazard. For local effect the drug should be sprinkled in a thin layer, as from a saltcellar, insufflated in a thin layer, or used in combination with carbowax which becomes fluid or semifluid at body temperatures.

14. Chemotherapy is effective against acute hematogenous osteomyelitis in the acute phase by systemic administration, and against acute exacerbations in chronic osteomyelitis. There is at present no valid evidence to show that it is effective against chronic osteomyelitis characterized by localization and bone sclerosis. (See also Chapter 16.)

15. In reconstructive procedures directed against nonunion and osteomyelitis with or without loss of substance, chemotherapy is not effective unless dead and infected bone is removed by surgical procedure. This and the preceding statement are more or less corollaries.

16. The systemic use of chemotherapy preceding reconstructive procedures following infected compound fractures, the local use at the time of operation, and the systemic use postoperatively are distinctly of value, provided all other phases of the procedure are based on sound surgical principles. (See discussion of reconstructive procedures below.)

17 The fact that the prophylactic use of chemotherapy in compound fractures has not yet been proved to have any definite effect on the morbidity to infection rate in a series of such cases is not to be construed as a contraindication to such use This statement is true only if the drug is used as an adjuvant to sound surgical practice but is not true if it is used as a substitute for such practice

For the special status of chemotherapy in military surgery see the information contained in Chapter 44

There may be many who will disagree with any or all of the foregoing statements on the basis of personal experiences and *impressions or on the basis of an adequately studied* but small and uncontrolled group of cases The statements nevertheless are supported by the evidence of large numbers of controlled cases adequately followed and evaluated and subjected to critical review by a responsible group and must take precedence over any such individual observations

Use of Sulfa Drugs

The systemic use of the sulfa drugs may have toxic effects Some individuals are abnormally sensitive to them Known kidney or liver disease constitutes a serious hazard in their use The toxic effects are evidenced by (1) leukopenia and relative lymphocytosis (2) albumin red blood cells and drug crystals in the urine and (3) in some cases jaundice and liver enlargement The blood count and the urine should be checked at least every other day during the period of the systemic administration of the drug and the drug discontinued if there is evidence of toxic action

It is considered desirable to maintain a blood level of not less than 10 and not over 12 or 13 mg per cent This level should be checked every two or three days as a guide to dosage

Reaction to the drug at times takes the *form of continued high temperature* after some days of administration despite adequate blood levels This must be kept in mind since discontinuance of the drug in these cases will result in drop in the temperature

Gastric distress accompanying mouth administration may often be alleviated by simultaneous mouth dosage of sodium bicarbonate

Sulfanilamide sulfathiazole or sulfadiazine may be used by mouth singly or in combination The former is most effective against the streptococcus the latter two have perhaps some advantages in staphylococcus infection Sulfadiazine is the least toxic of the three sulfanilamide the most *In general today sulfadiazine is the drug* most commonly used The initial dosage is usually 2 Gm followed by 1 Gm every four hours day and night until the desired blood level is reached and then dropped to 1 Gm every six hours or less as indicated by the blood level maintained

In severe general infection where it is desirable to attain the necessary blood level rapidly the initial dose may be 4 or 6 Gm or the sodium salt of sulfadiazine may be given intravenously 2 4 or 6 Gm in a saline infusion and the blood level then maintained by the four or six hour dosage of 1 Gm Fluid intake should be adequately maintained

In the local use of the drugs the powder or crystals should be sifted or insufflated onto all wound surfaces in a thin layer under adequate exposure It is unnecessary and disadvantageous to use larger amounts as there is evidence that excess of the powder interferes with wound healing Any of the three drugs named may be used or they may be used in combination—sulfanilamide and either the thiazole or the diazene The latter is more commonly used in the combination

The drugs may be used in carbowax as an ointment like preparation which becomes fluid at body temperature to invade all portions of the wound or the wound may

be loosely filled with gauze impregnated with this preparation.

The sodium salts, because of their high pH (around 11.0), have so far been considered too irritating to use locally. Their solubility would be an advantage.

Experience with the use of micro-crystals of the drug is being gained which may show advantages for this form.

Use of Penicillin

The systemic use of penicillin may be by the intravenous or the intramuscular route. If the former, the proper dosage must be given every two hours day and night; if the latter, the administration can be at three-hourly intervals. This frequency of dosage is necessary to maintain adequate blood levels, since elimination is rapid.

The average dosage should be from 80,000 to 120,000 units per day for a total of 1,000,000 or more units. Underdosage may lead to acquirement of resistance by a certain percentage of the organisms. A solution of 1,000 units per cubic centimeter is usually used.

The toxic symptoms from penicillin to date have been infrequent and not serious. Urticaria, temperature reaction similar to that seen with the sulfa drugs, and some instances of phlebitis have been noted.

Sodium penicillin is used for systemic administration.

In the local administration of the drug calcium penicillin is used. The solution strength is usually 250 units per cubic centimeter. It may be put directly into the wound, or used with fine-meshed gauze packing, or it may be instilled at intervals through a fine tube or tubes in the wound. The amount used depends on the size of the wound.

Calcium penicillin thiazole locally has been extensively used by the British and Canadians in World War II and there are encouraging reports as to increased efficiency of action, both for prophylaxis against wound infection and for treatment of established infection. Further experience and knowledge are needed on this score.

The treatment of suppurative arthritis by repeated aspiration and the instillation of calcium penicillin or calcium penicillin thiazole into the joint has produced some remarkable results, and should be thoroughly considered. (See comments on this score in Chapter 44.)

The use of chemotherapy in the treatment of hematogenous osteomyelitis is discussed in Chapter 16. The dosages are as indicated here, and the use of penicillin is subject to the same comments as are here made concerning its use in conditions of traumatic origin.

GAS-BACILLUS INFECTIONS

These, of course, are the bête noir of the surgeon dealing with compound fractures. Fortunately, the morbidity rate is low and is still further diminished, insofar as clinical development is concerned, by adequate and intelligent primary wound treatment, the principles of which have been discussed in the section on compound fractures. No detailed discussion of the etiology or pathology and bacteriology of this condition is to be presented here. The discussion will be limited to the treatment of the various types of infection which are seen.

These are three in the group of cases ordinarily known as the gas infections—one is a cellulitis involving the tissues immediately beneath the skin, the second is characterized by local abscess formation, and the third is an invasive spreading infection of the muscle planes. The two former are relatively innocuous. They do not make the patient particularly ill; they respond readily to adequate surgery of incision and drainage plus the use of anti-gas serum and local chemotherapy, particularly calcium penicillin. The local use of zinc peroxide as a paste filling the wound, and kept moist, or in a carbowax mixture, as developed by Meleney, is effective in these cases. It is also effective, used with adequate surgery,

against the facultative anaerobes acting in symbiosis with the staphylococcus and against the micro aerophilic streptococci These infections are characterized by gradually extending skin slough with undermining of the skin edges which presents quite a characteristic appearance

The third group is the severe and dangerous type To be successful treatment must be instituted early and pursued intensively The patient with high temperature inordinately high pulse rate and soft pulse and who is more or less euphoric is the suspect He feels well but looks prostrated The characteristic sweetish odor to the wound the skin discoloration palpable crepitus in the tissues and the x ray demonstration of gas bubbles are the clinching features Muscle necrosis which may be rapid and massive and extension along the neurovascular channels are characteristic

Local operative procedure is indicated as described below The surgical treatment apart from operative measures calls for the use of massive doses intravenously intramuscularly and locally of anti gas serum preferably polyvalent and the systemic and local use of chemotherapy The use of the sulfa group of drugs has been disappointing in this respect although effect has been reported The serum alone plus local operative measures has frequently led to recov^ry but has often been disappointing There are increasing reports suggesting that the use of adequate local *operative procedures plus the systemic ad*ministration of sufficient anti gas serum and calcium penicillin and the local use of calcium penicillin or calcium penicillin thiazole leads to remarkably improved results To be effective the treatment must be instituted early the dosage must be adequate and adequate early operative procedures must be employed

The operative procedures indicated are of two types If the extent of involvement is such as to allow of it and to make it worth while the area should be widely exposed all dead and necrotic muscle should be completely *excised* (whole muscles or muscle groups if necessary) the wound kept wide open and local and systemic treatment by drug and serum instituted

If the extent of involvement renders this impossible or if a useless extremity would be the result amputation well *above* the uppermost level of involvement should be done All such amputations should be guillotine in type with no attempt at closure The stump should be carefully inspected for muscle involvement or for evidence of gas in the neurovascular channels as evidence for need of tissue excision or higher amputation

If the amputation cannot be done above the involved level it must of course be done at the highest possible level through infected tissue

The amputation stump is subjected to the local treatment outlined above in addition to systemic treatment

RECONSTRUCTION SURGERY

The attack on this problem has undergone a remarkable revision under the impact resulting from the demands of the present war *Faced with the problem of* saving numerous extremities exhibiting marked loss of soft tissue and skin loss of bone substance bone necrosis infection and vascular damage and in patients showing marked general deficiencies impairing their wound healing powers and their abil*ity to control infection the investigators in* this field have developed a planned approach to the problem The approach utilizes the value of sound surgical principles helped by all the adjuvants which have been uncovered as aids in the face of the local and general situation

Indeed one is moved to wonder sometimes whether or not the theoretical gains made by reason of such planned accomplishments are actual and practical ones particularly from an economic standpoint There is real and honest food for thought

in the suggestion that in many instances the technical success of the procedures employed may be more than outweighed by the length of time taken to accomplish the result, the expense involved, and the ultimate practical value of the reconstructed extremity. A relatively simple amputation at an elective site, with a short convalescence and a rapid rehabilitation in a lower extremity, may provide a much sounder and more practical solution to the problem presented than does a prolonged and complicated series of procedures which can at the best produce an imperfect extremity constituting an inherent permanent hazard in any active uninhibited existence.

The economic import of the time factor involved, the age of the patient, his psychology in respect to the loss of the extremity and the wearing of an artificial limb, his normal occupation, his adaptability in respect to acquiring new skills and to the entering of new fields of endeavor—all these are matters of prime importance in evaluating the situation. There is not much sense in spending months of time and effort at a great deal of expense for the production of a reconstruction which, however technically perfect, serves no practical purpose. These are the various factors which must be analyzed in coming to a decision as to whether or not reconstruction is sound in many of the more severe injuries of the lower extremity. Only after such a decision is it worth while to plan such a program.

In the upper extremity, by comparison, there is frequently much more justification for expenditure of time, effort, and money to save every possible remnant of normal structure. The fine and skilled movements possible here are ill substituted for by prostheses, whereas the gross functions of weight-bearing and shifting weight-bearing in the lower extremity may be adequately cared for by this means. Particularly is this difference apparent when one considers the hand. It is true that much can be accomplished by good prostheses in a particularly apt and ambitious patient, notably by the use of cineplastic stumps and appliances, but the means of practical accomplishment is far below that attainable in the lower extremity. One, therefore, is justified in spending an amount of time, effort, money, and ingenuity in salvaging all that is possible in an upper extremity which would perhaps be unsound and unjustified in dealing with a lower extremity. One might almost say that in the presence of an equivocal situation it is necessary to justify refraining from amputation in a lower extremity, and amputation in an upper extremity.

If reconstruction procedures are decided upon in any given case, it is well to have as a basis for procedure an overall view of the problem as a whole in terms of all the possible factors which may have to be dealt with. If one has such a conception, the various factors in the individual case can be dealt with as individual problems, if they so exist, or as individual parts of the general problem in which the timing and nature of the individual procedure must be correlated with the other factors involved in the general picture. The bone grafting of a simple nonunion in a healthy individual presents a problem quite different from the same nonunion in a generally debilitated and specifically deficient patient who has sustained severe local soft-part injuries even though the latter be apparently completely healed. The x-ray pictures may be identical, but the problem is far from being the same in the two instances. Success or failure in the grafting procedure in the two cases may depend upon the recognition of this difference.

In order to insure the optimum chance of success in any reconstructive procedure or course of procedures, one must take cognizance of the individual, of the condition of the soft parts at the site of the proposed operation, of the condition of the bone at that site, and of the nature of the proce-

dure planned Insofar as bone grafting itself is concerned, it is an essential that the graft ultimately be incorporated as an integral part of the host bone and that it continue to exist as such It may be highly desirable that considerable new bone form and persist about the incorporated graft in order to meet functional demands Length and alignment adequate to meet functional needs must be preserved during the period preceding grafting or restored at the time of grafting The incorporation of the graft in the host bone and the production of new bone in its vicinity involve factors concerned in bone growth and repair which are discussed elsewhere in this chapter in connection with the healing of fractures Suffice it to say here that from a practical standpoint the problem involves the placing of the graft in an environment providing an adequate source of new formed undifferentiated connective tissue (granulation tissue) and a rich and efficient minute circulation (tissue space, lymphatic and ultimate capillary) plus the elimination or reduction to a minimum of any and all sources of local irritation or inflammation

The attack on this problem may have to be along any or all of the following lines depending on the conditions present in the individual case

Preoperative

1 Attention to deficiencies in the systemic factors involved in the normal healing of wounds Dehydration, marked weight loss evidencing severe depletion of protein levels in the blood (verified by serum protein determinations as described earlier in this chapter in the discussion of Shock), blood volume and hemoglobin loss as evidenced by hematocrit and blood count studies, and vitamin deficiencies in conjunction with weight loss and diminished appetite and food intake are the major factors Adequate fluid intake, by parenteral means if necessary and high caloric high protein–high vitamin diets, plasma, and whole blood transfusions (the latter always being preferable) are among the resources available to restore the patient from these deficiencies if present before any bone reconstruction program is started

2 Attention to active local infection by adequate drainage, thorough removal of dead and infected bone and foreign bodies and the local and systemic use of chemotherapy (see earlier in this chapter)

3 Systemic chemotherapy as a safeguard against the flare up of possible latent infection at the operative site

4 Allowance of sufficient time lapse after apparent complete control of wound infection and healing before reconstructive procedures are attempted

5 Plastic procedures if necessary after infection and wound healing are controlled to provide the environment of new tissue source and adequate minute circulation necessary for the successful bone reconstruction If used preceding the actual bone procedure the plastic procedures must be employed sufficiently long after control of infection and wound healing to insure their success and be of such nature and sufficiently in advance of the bone reconstruction as to provide the necessary tissue and circulation sources at that time

6 Attention to improvement of the local circulation by exercise and active use where possible, to improve deficient muscle tone and volume by physical therapeutic substitutes for exercise and active use by pressure dressings or supports and by positional (Buerger exercises) and gravity (moderate elevation) aids An atrophic and flabby extremity which has been inactive or immobilized for months is far from ideal for bone reconstruction procedures

Operative

1 Plastic procedures at the time of bone reconstruction to provide adequate tissue source and circulatory environment when indicated

2 The use of local chemotherapy at the

time of operation as a safeguard against flare-up of latent infection.

3. Minimal operative trauma to the surrounding soft parts, both in the nature of the approach and in the handling of the tissues.

4. Removal of scarred tissue and bone sufficient to obtain adequate vascularity of the region.

5. Adequate fixation of the graft. In general the more rigidly fixed the graft the greater its chance of success. Incompletely fixed grafts may, of course, be successful, but the maximum chance of success lies in rigid fixation. When a dense fibrous union exists, without a loss of substance and resultant gap between fragments, the simple "laying on" of a graft through subperiosteal exposure in a vascular area (the posterior face of the tibia, for example) as practiced by Phemister, without fixation of the graft other than by the overlying tissues and without excision of the fibrous union between fragments, may be very successful.

6. The use of grafts of adequate length Where possible, the graft should be at least two and one-half to three times the length of any defect present. Where little or no actual defect exists, the length of the graft should be three times the diameter of the bone, or longer if possible.

7. Closure without tension in the soft parts surrounding the graft.

The necessity for maintaining completely normal length at the expense of a gap between fragments (which has to be bridged) always needs serious consideration. In most instances in the upper extremity this is not necessary, and grafting with the ends of the fragments contacted is simpler, more certain of success, and shortens the convalescence time without causing functional disability. In the lower extremity it is probably true that at times the attempt to maintain full length at the expense of employing a more difficult and more precarious procedure with a prolongation of convalescence time is difficult to justify. The acceptance

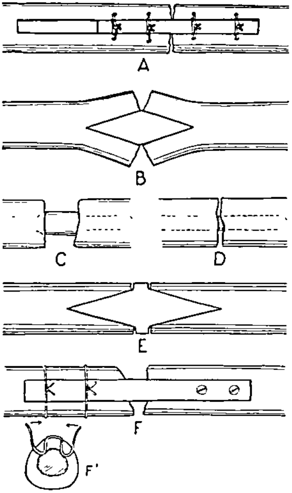


FIG. 557. Methods of bone grafting. (A) Sliding inlay. (B) Diamond inlay. Inlay here is removed from elsewhere It may be mortised as in (E) below (Albee), or it may be wedged, as here, by splitting end of each fragment and "springing" split ends (Gallie). (C) and (D) Intermedullary peg grafts (C) is a "shouldered" graft to bridge a defect. Bone chips or osteoperiosteal grafts may be used to further fill the gap. The peg is carefully formed to fit the medullary canal. (E) Mortised diamond graft. (F) Onlay graft. In the sliding graft, graft comes from site of injury. In the onlay graft it is taken from elsewhere. Any gap caused by loss of substance may be filled with chip or osteoperiosteal grafts. Grafts in (A) or (F) may be fastened in their prepared channels by wire or chromic-gut sutures or by stainless-steel or vitallium screws. If wire or gut is used, method of passing suture with aid of drill holes is illustrated in (F^1). It may be merely passed around the bone to include graft, but this is not so satisfactory.

of a reasonable amount of shortening in return for the advantages of grafting contacted fragments may be far more sound and logical The shortening can be compensated for Both Smith Petersen and John Royal Moore take this viewpoint (personal communications)

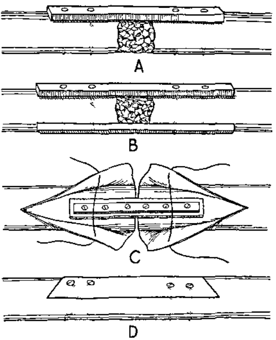


Fig 558 Bone grafts (A) Henderson onlay graft, with bone chips or osteoperiosteal grafts filling a defect due to loss of substance (B) Double onlay graft of Boyd (C) Osteoperiosteal onlay of McBride, with a plate superimposed for fixation, screws passing through graft and both cortices of subjacent bone (D) Wide beveled onlay on prepared surface (Hey Groves, Kirk), screws may be placed in either of the ways shown

Various methods of internal fixation of the graft in the host can be used Vitallium screws, stainless steel wire, stainless steel screws and vitallium or stainless steel plates are all employed for this purpose Two different metals should not be used in conjunction, as brought out by Venable Chromic gut is still used by some, but wire has largely replaced it Self fixation of the graft by undercutting or wedging is also used alone or in conjunction with internal fixation means External fixation by plaster, by pin and plaster, or by pin and apparatus is used with or without internal fixation The commoner practice today is probably internal fixation plus circular plaster which immobilizes the contiguous joints

The various types of grafting which are in use are illustrated in Figs 557 to 560 Many of these are drawn after those shown in the excellent article by John Royal Moore (Jour Bone and Joint Surg, 26 23)

All the technical details discussed earlier in this chapter in reference to the open reduction of fractures hold true for the operation of bone grafting and should be carefully observed

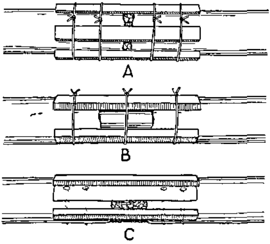


Fig 559 Bone grafts (A) Barrel stave graft of Steele, (B) combination of barrelstave and shouldered intermedullary peg grafts (see Fig 557 C), (C) combination of barrelstave and wide beveled onlay (Wilson) (Compare Fig 558 D)

The graft, and the bed prepared for it, may be cut by the use of a motor bone saw or by thin and very sharp osteotomes When the motor saw is used, the author feels that one of the types which has a rheostat control of speed of revolution is advantageous, and that it should be used at as low a speed

as is consistent with cutting in the bone concerned. The generation of often extreme degrees of heat by the saw blade at high speed is, in his opinion, a definite disadvantage. For this reason he is personally in favor of the use of thin and very sharp osteotomes for this purpose.

Postoperative

1. The period of postoperative fixation must, naturally, show considerable variation because of the variations in soft-part circulatory efficiency and bone density encountered. In general it can be said that 12 weeks represents the minimum time required in the lower extremity, and that this may have to be prolonged to 24 weeks or more. The larger the gap to be bridged, in general, the longer the period of immobilization required. In the upper extremity 6 to 8 weeks may be adequate time. More frequently 8 to 12 weeks are called for, and in the presence of relatively poorly vascularized tissues 12 to 16 weeks' immobilization may be necessary. The criterion as to union is the x-ray appearance of the site. The x-rays should be taken with external plaster removed if they are to be of any real value. X-rays for position can be taken through the plaster during the healing period, of course. It is astonishing how often, however, x-rays taken through plaster are used as criteria whereby to judge the character and extent of the bone healing.

2. The systemic use of chemotherapy may be indicated as prophylaxis against the development of latent infection in accordance with the methods described earlier in this chapter.

3. Attention to deficiencies in the systemic factors involved in wound healing and control of infection, as described in preoperative procedures, may have to be continued for some time postoperatively as indicated by the usual clinical and laboratory criteria.

4. Mobilization of the patient as a whole as early as possible is a definite advantage from the standpoint of circulatory and metabolic activity and from the standpoint of morale.

5. Frequent active exercise of all joints in the extremity which the necessary im-

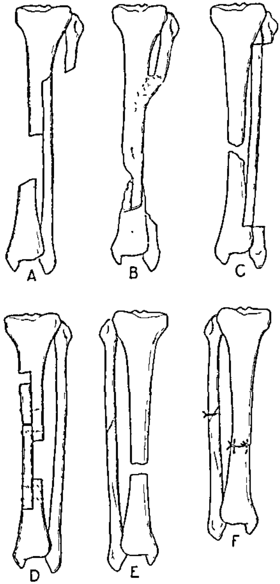


Fig. 560. Bone grafts. For massive defects. (A) and (B) Two-stage fibular bridging (Huntington). (C) One-stage fibular bridging (Wilson). (D) Sliding massive onlay. (E) and (F) Moore's fibular oblique section, with freshening and squaring of tibial edges and wiring of both bones. This is a simplified procedure which sacrifices length for simplicity and for increased certainty of union.

mobilization will allow of within pain and fatigue limits is a very definite aid to the efficiency of the minute circulation

6 Even though joints have to be immobilized voluntary exercise of the muscles which would ordinarily move them can be taught to the patient and the frequent use of these exercises within pain and fatigue limits is of definite value in maintaining active and efficient minute circulation Indeed the active mobilization of joints possesses value more because of the muscle action entailed than by reason of the joint movement

7 Following the removal of fixation physical therapy measures can be of material aid in helping functional rehabilitation if used as adjuvants to the patient s active efforts and not as substitutes for them

8 When the immobilization is removed because of x ray evidence of union brace support is indicated in the lower extremity until x ray evidence of union is complete and homogeneous As soon as the brace support will allow it crutch and cane should be discarded Their continued use when they can be gotten rid of does much to delay the patient s resumption of normal weight bearing and activity

The adequate carrying out of the post operative regime may do much to promote increased chances of successful take of the graft and to shorten rehabilitation time It is a serious mistake to let a patient lie around in plaster in the hospital or at home passively waiting until and if x ray findings warrant activity without plaster The operation itself is often viewed as the whole story just as the reduction and immobilization is often and erroneously regarded in fracture treatment but the chances of a successful operative result and the shortening of the time needed for rehabilitation of the patient and his extremity may be materially influenced by proper postoperative handling directed towards the re-establishment of a normal physiology and a proper psychology

Physical Therapy

Physical therapy can be used to help meet two needs in the treatment of fractures

In the early stages for the first ten days following the injury it can be of aid in getting rid of the accumulation of the products of tissue death of extravasated and broken down blood and of inflammatory exudate and edema This it does by relaxing muscle and vascular spasm and by mechanical aid to the minute circulation All the modalities of physical therapy which can accomplish these purposes should therefore be of value

The net result of such aid to the minute circulation of the part should be reflected in less thickening and fibrous tissue organization in the soft parts with the implication of earlier and easier recovery of function and in aid to the fracture healing process by early removal from the part of the acid products of tissue death and inflammatory exudate and broken down blood which may be a deterrent to the early and adequate deposition of calcium in the healing tissue

Light stroking massage of the sedative type constant or prolonged periods of gentle heat and mechanical substitution for the milking action of normal nonspastic muscle action would seem to cover the field coupled with moderate elevation of the part and the voluntary exercise of whatever muscles in the extremity the method of fracture treatment renders possible The heat can be simply supplied by an ordinary gooseneck lamp beneath a blanket or sheet tent over the part The essential feature is that it keep the part warm—not hot—and that its action be prolonged Baking machines can be used if the heat is kept low and if they are used for considerable stretches at a time The so called heat lamp or therapeutic lamp or the infrared ray can be used with the same restrictions Diathermy must be used with the same idea in mind and should therefore be of low mil

liamperage (between 150 and 250 amperes) and for as prolonged periods as possible.

The common error in the use of heat is the employment of too great intensity for short periods. The net result is to produce local congestion and minute circulatory stasis, defeating the object of treatment. The lower ranges of heat employed for prolonged periods have a sedative action on muscle and vascular spasm.

For mechanical aid to substitute for normal muscle "milking" action on the minute circulation, one can make use of the positive and negative pressure boots which are used in vascular disease, muscle massage may be utilized, and the electrical stimulation of available musculature may be practiced. All of these means, if used, must be so used as not to cause pain or discomfort, for the muscle and vascular spasm which pain and discomfort evoke defeat the purpose of the treatment. When electrical stimulation of muscle is used to substitute for voluntary muscle exercise it must be in a form which induces a facsimile of normal muscle contraction without spasm. This can be secured by using a very rapidly interrupted current, the intensity of which can be slowly and gradually increased and diminished to produce rhythmic, spasmless, and slow alternating contraction and relaxation of the muscle. Some of the sinusoidal machines can do this, and more particularly the Smart coil (sometimes erroneously called the Bristow coil), which utilizes a mercury interrupter capable of high speed of current interruption and hand manipulation of the core within the coil, approaches most nearly, the author believes, the normal muscle contraction mechanism. There are a great many details in the carrying out of this type of electrical muscle stimulation which require expert handling to make it effective. Ordinary galvanism or faradism is of no value and do not reproduce normal muscle action.

Any voluntary muscle activity which the fracture-treatment method will allow of will be of value insofar as it is free from spasm and is painless. All muscle exercise should be given for only a few minutes at a time, increased amount of exercise to be gained by increasing the frequency of the short periods rather than prolonging the length of the individual periods *Any physical therapy or exercise therapy which causes pain or discomfort loses a large part if not all of its value* in this early stage. All should be used short of pain and discomfort limits, and, in fact, should reduce the pain and discomfort present if they are really being of value. How much all this therapy is indicated in the early stage depends upon the difficulty to be encountered in administering it properly, and the need for it as denoted by the amount and character of the obvious tissue changes.

In this connection, when the early swelling and tumefaction following fracture is great and excessive, a paravertebral or brachial block will often result in rapid and remarkable relief by its effect on vascular and muscle spasm. This is particularly true in crushing types of injury, and in those in which early extreme and exquisite pain is a feature. It is not necessary or indicated in the ordinary "run-of-the-mill" case.

In the late stages of fracture treatment—the stage of so-called after-treatment—it is the author's belief that it is not the rôle of physical therapy to rehabilitate the patient. It should be used distinctly only to make it easier for the patient to rehabilitate himself. Relaxation of spasm to relieve pain and motion limitation so that exercise and function can more readily be carried out, mechanical aid to the minute circulation, instruction in the means of gaining functional activity, plus guided aid and resistance, relief from the pain and stiffness after exercise—all these are the motivations which should be behind the use of any of the numerous modalities which physical therapy has to offer, rather than the real or theoretical benefit to be temporarily

offered by the treatment itself In the early stages *the treatment itself* plays a major role In the later stages it is but the means to an end When this is thoroughly realized by all technicians and notably by the doctors who order and use physical therapy the value of this aid in fracture treatment will be immeasurably increased

LOCAL ANESTHESIA IN FRACTURES

This may be used in any fresh fracture in which fluid hematoma exists at the fracture site It is of particular value when general *anesthesia is inadvisable Its use is usually* unwise in the very apprehensive in the emotionally severely disturbed in those with local skin lesions risking infection and in children In multiple lesions as a Colles with a fracture of the ulnar styloid each site must be separately injected

Technic The skin is shaved and cleaned thoroughly with soap and water alcohol and ether A skin antiseptic can then be used The author prefers mechanical cleansing without the antiseptic Careful asepsis is important Sterile draping and gloves are always indicated A wheal is raised in the skin with 2 per cent novocaine A skin nick is made A fresh long small gauge needle is applied to the syringe and is passed through the skin nick to the fracture site 1 per cent novocaine being injected slowly ahead of the needle The fracture site is located using the needle as a probe the plunger of the syringe is partly withdrawn If the needle is in hematoma blood will enter the syringe If not the location of the needle point is changed and aspiration again tried If no blood can be aspirated anesthesia is apt to be poor If blood is obtained 20 to 30 cc of 1 per cent novocaine is injected into the hematoma the needle withdrawn and a sterile dressing applied Anesthesia should be adequate after 10 to 15 minutes

DELAYED AND NONUNION

These present the same problems to a less degree that are met with in reconstructive surgery The condition of the patient himself may present no problem and the elements of infection and deficiencies in relation to the factors involved in all wound healing are less apt to require attention A local circulatory deficiency is usually the factor when the treatment of the fracture has been adequate This problem is met exactly as it is in the actual bone reconstructive procedure by bone grafting In simple long delayed union or nonunion however mere drilling of the bone fragments using multiple drill holes crossing *the fracture line from one fragment through* the other is sometimes used before resorting to grafting if the surrounding tissues are sufficiently vascular to offer reasonable hope of granulation tissue and capillary growth from them through the channels so established In this instance the tiny bone fragments created by the passage of the drill may be considered as multiple minute chip *grafts Postoperatively the same immobili*zation and after treatment are required as would have been the case in a grafting procedure When the bone at the fracture site is extremely sclerotic or when the soft parts surrounding the fracture site are fibrous and avascular the chances of success are not good It is a procedure more logically applicable to a delayed union *than to a frank nonunion The latter is more* apt to require grafting procedures

When delayed union is present its rate of progress can sometimes be hastened by non operative measures which will allow of muscular activity with sufficient immobilization to prevent shift in axis or rotation or loss in length The so called walking iron or walking plaster or adequate braces in the lower *extremity and braces in the upper extrem*ity are such means Their trial is indicated however only when evidence of possible union is present but the rate of union is slow and the callus scanty Their only purpose is to increase the efficiency of the minute circulation through muscular activ

ity without allowing any dangerous degree of mobility or strain at the fracture site.

MYOSITIS OSSIFICANS

Myositis ossificans may complicate fracture or muscle trauma without fracture. Some discussion of this complication is presented in connection with elbow fractures in Chapter 31. When it does occur as a complicating factor it is well to remember that early intensive attack on it by operative removal, intensive physical therapy, or forced motion (active or passive) usually results in increase in the amount, density, and speed of the bone formation. The formation of bone in these cases goes through a cycle of three stages. The initial stage is one of increasing amount of lightly calcified bone with indefinite borders as seen by x-ray. This period lasts for from two to four months, and is succeeded by a second stage in which the amount remains stationary, but the borders become progressively more definitely defined and the density of the mass as a whole increases. This period lasts for from three to six months, and is followed by a period lasting about the same length of time during which the mass becomes progressively smaller and denser. This may eventuate in complete disappearance of the bony mass or in its shrinking to an irreducible minimum which then remains stationary in size and density.

During the first stage, treatment directed against the condition must be limited to such gentle active motion without pain or spasm as is possible, and physical therapy is best omitted. Under no circumstances should active motion be forced, or should passive motion be used. Physical therapy, if used, should be of the gentlest and mildest type—purely sedative in nature.

During the second stage this course must still be held to. Attempts to hasten the issue by intensive physical therapy, by forcing of active motion or by operative removal in either of these two stages in most instances results in increase in the amount and density of the bone formed. It is a difficult thing to keep from trying to do something. The carrying of heavy weights, for instance, in elbow cases may be definitely harmful. *It is also difficult to persuade patients* or their parents that seeming therapeutic inactivity is the part of wisdom. Active use within the limits of pain, spasm, or fatigue, and the mildest of sedative physical therapy are called for.

When the third stage is reached, excision may be done of the well-defined residue without recurrence of bone formation, to be followed by increasing exercise and physical therapeutic measures. Even then recurrence is sometimes seen, and it is the author's opinion, on the basis of bitter experiences over a number of years, that it is wiser to wait until the mass has reached its minimum and has been stationary for several months before attempting operative excision. One can feel reasonably sure that recurrence will not take place at that time if careful dissection of the mass is carried out.

In the elbow, the scar tissue in the anterior capsule and in the brachialis anticus in which the bone has formed may still be a bar to full extension and a capsuloplasty may be necessary following the excision.

VOLKMANN'S ISCHEMIA

This complication occurs usually in the forearm affecting the wrist and hand. It is most commonly associated with supracondylar fracture of the elbow (see Chapter 31), but is occasionally seen in fractures of the forearm bones associated with unusual hemorrhage beneath the deep fascia or with too tight splinting of the fracture. Prophylaxis against it in elbow fractures is discussed in Chapter 31. It is practically never necessary to incise the deep fascia of the forearm in supracondylar fractures to relieve this threat. When the threat accompanies forearm fractures, as evidenced by pulse diminution, coldness and numbness of the hand with color change, and weakness of finger motion, and is not promptly re-

lieved by removal of any constriction by splint or bandage, the indication is for extensive incision of the deep fascia of the forearm, including the lacertus fibrosus, to relieve the tension occluding the vessels The skin should not be extensively incised, as closure in the swollen condition of the arm is difficult The long line of incision *through the fascia can be accomplished* through several short successive skin incisions in a longitudinal line, allowing skin closure, the long continuous incision or incisions in the fascia being left wide open

Once the condition becomes well established, which may be within a few hours, this procedure may be too late to prevent *the characteristic changes*

Established Volkmann s ischemic paralysis is a catastrophe The prognosis is poor under any method of treatment, the results of all methods being disappointing

In the early stage of paralysis and before the occurrence of contracture, moderate elevation and heat, followed by the early institution of elastic traction on the wrist and fingers up to the point of tolerance in extension, using a banjo or cock up dorsal splint, may minimize the extent of subsequent deformity by contracture, and may be aided by the use of physiotherapeutic measures designed to aid circulatory efficiency, and exercises Even the early use of a cock up splint in extension for the wrist and fingers without elastic traction will help in this respect, although it is not so effective

When the contracture has already occurred, the methods of treatment are those described over a long period of time until no further improvement can be noted, followed by, if necessary, operative shortening of the forearm bones or transplantation of the internal condylar muscle attachments with a block of the humerus down on to the shaft of the ulna a sufficient distance to diminish the amount of contracture caused by the fibrosed and shortened flexor muscles *The use of elastic traction, cock up* splinting, active exercise, and physical therapy entails a long and arduous course The patients get discouraged and unco operative and require considerable supervision The operative results are, in general not too encouraging, although occasionally very satisfactory, considering the condition being dealt with

With a particularly co operative patient *under* adequate supervision for a long enough time surprisingly good results can be secured in forearm cases by the conservative therapy with or without the addition of the operative procedures cited

Occasionally this condition occurs in the lower leg as a result of hemorrhage from the tibial vessels or unduly tight splinting *The general condition and the course of* treatment indicated are similar to the procedures used in the forearm, and are designed to relieve the tension, to minimize contracture, and to correct it if it has occurred insofar as possible

Hemophiliacs occasionally develop Volkmann s contracture of the forearm or lower leg as the result of spontaneous hemorrhage beneath the deep fascia without trauma In these cases operative procedures are, of course, contraindicated *and the* conservative therapy is particularly unsuccessful

SUDECK S ATROPHY

This marked and spotty atrophy of bone, usually accompanied by considerable pain and often by evidence of soft part circulatory disturbance is a distressing complication seen in fracture, or sometimes, after sprain, or after contusion of bone It is apparently secondary to sympathetic vascular disturbance *Buerger exercises* and moderate elevation will relieve mild cases, and can be augmented by the use of voluntary muscle exercises with or without joint motion The use of the positive and negative pressure boot, even for an extremity in plaster, will frequently be of great benefit The institution of as early function as possible is of value, and the early use of physical therapy designed to relieve vascular and

muscle spasm will aid when it can be used. The more severe cases can frequently be relieved by lumbar paravertebral or brachial block, particularly if employed early, in association with the other measures mentioned.

In the more resistant cases, periarterial sympathectomy or ganglionectomy may be needed. Either of these procedures should be employed, if they are to be used, before the lapse of too many months—probably within the first six months—as otherwise the result is apt to be disappointing.

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23

Compound Fractures

William Darrach, M.D.

DEFINITION

Compound fractures are usually defined as fractures which are complicated by a wound of the skin which communicates directly with the site of the break. The importance of this complication is that it furnishes a source of infection. Infection interferes with the healing process of the bone. It may also be the cause of spreading cellulitis, osteomyelitis, or severe and even fatal sepsis. Even though the wound in the skin does not communicate directly with the fracture site originally, the infection may spread through the intervening tissues to the bone lesion. The practice of probing a wound to find out whether it communicates with the site of fracture is condemned. It is wiser therefore to consider any fracture as compound which has a wound through the skin in close proximity to it.

The complicating wound may be caused by the direct force which breaks the bone or it may be due to the penetration of the skin from within by the end of one of the bone fragments. It is true that if the wound is made from within, the amount of contamination carried to the deeper planes is less than if the wound is made from without, but even a small punctured wound may be followed by infection of a serious nature. Any fracture that is complicated by a skin wound in the immediate neighborhood should be considered compound and treated accordingly.

PATHOLOGY

Displacement of the fragments of bone almost always occurs in compound fractures. There is often comminution of the bone. With these there is considerable soft-part laceration. Extensive soft-part damage results in delayed union of the broken bone, even in closed fractures. In compound fractures there is the added menace that the devitalized fat, fascia, and muscle provide excellent culture media for the invading bacteria. Contaminated matter may be carried into the wound by the original trauma or by improper first-aid treatment. Portions of skin, clothing, dirt, or the traumatizing agent itself, such as bullet, shell fragment, bit of wood or metal, may enter the wound.

At the original injury, the end of a broken bone may protrude through the skin, and even through the clothing, and thus come in contact with infective material. If the bone is pulled back into the wound it will carry with it many bacteria.

As the patient is lifted and carried from the site of accident, unless the injured part is well immobilized, there will be further churning of the bone fragments in the adjacent soft parts with additional laceration and the thorough sowing of bacteria in a fertile field. Unless the wound be protected, more infective material may be introduced by the rubbing of clothing against the wound. When the wound is caused from within and the end of the broken bone im-

mediately withdrawn from the wound, the amount of infection may be small Such a wound may heal with no evidence of infection, but if infection does occur the small wound brings the disadvantage of allowing insufficient drainage and so increasing tension in the traumatized region This in turn interferes with local blood supply and so favors bacterial growth

The amount and severity of infection which may develop in such a wound is influenced by a number of factors

1 *The character of the contaminating material* Street dirt (especially if there is horse traffic) and recently manured fields are very apt to contain gas forming and tetanus organisms

2 The amount of soft part damage

3 The amount of secondary trauma caused during transportation of the patient and the examination of the injured part

4 The development of infection is favored by anything which interferes with the local blood supply, such as tight bandages, tourniquets, dependent position of the injured part, general shock, and exposure

5 Perhaps the most important factor—at least the most important controllable factor—is the time which elapses between the original injury and the adoption of suitable treatment The process of infection is well under way within very few hours, spreading throughout the injured area and invading the adjacent tissues

TREATMENT

General Principles

The chief objectives in the treatment of compound fractures are (1) To reduce to a minimum the secondary trauma of transportation, examination, reduction, and immobilization, (2) treatment of shock (3) to limit and control the infection (4) to restore the normal relationship of the bone fragments as rapidly and completely as possible, (5) to maintain this position during the process of repair, (6) treatment of the wound (7) to restore the function of the muscles and joints of the affected parts

Reduction of Secondary Trauma This is largely a question of first aid treatment and transportation As qualified surgeons rarely are present at the time of accident this must depend largely on the actions of the bystanders The present educational campaign in first aid instruction by the Red Cross, Boy Scouts, and other organizations should receive the enthusiastic backing and help of the medical profession Whenever efficient splinting and careful handling of the injured patient can be carried out the outcome will be greatly improved The effects of careless handling may be worse than those of the original injury The injured patient should not be moved until some form of splintage has been applied to the injured part If a Thomas or similar traction splint is not available, some form of rigid support must be bandaged to the extremity to avoid motion of the broken bones and the resulting additional soft part injury and spreading of the contamination When an ambulance is not available some form of truck or station wagon where the patient can be placed horizontal is much better than any passenger car

First Treatment of Shock This consists of morphine and protection against cold Excessive heat may do harm by increasing the loss of body fluid Except in extreme cases where the patient is almost moribund, further treatment by intravenous administration of plasma, saline, glucose, or blood can be given while the operative procedures are being carried out The best way to prevent further shock is to attend to the wound reduce the displacement, and put the injured part at rest at the earliest possible moment

Control of Infection This requires immediate protection of the wound to avoid additional contamination early operative removal of the infective material and devitalized tissue, the use of sera and drugs, and the postoperative care of the wound

If a sterile dressing is not available the cleanest bit of material at hand should be snugly applied to the wound. Bleeding can almost always be controlled by moderate pressure over the wound and elevation of the injured extremity. Only in severe hemorrhage will a tourniquet be necessary. Its use should be avoided if possible.

After proper splinting the patient should be transported to a hospital. Here the passage to the operating room should be delayed only for the necessary x-ray and other examination, unless extreme shock requires preliminary treatment.

Operative Technic

The object is to convert a contaminated wound into a surgically clean one at the earliest possible moment. Débridement aims to remove all foreign material and devitalized tissue.

The patient is placed on the operating table and anesthetized. With the traction splint still in place, the wound is protected by a small compress and the adjacent skin shaved and cleansed over a wide area. The skin margins of the wound are then excised and the latter enlarged enough to give free exposure of the whole injured area. All devitalized fat, muscle, and fascia are dissected away and foreign material removed. Small detached fragments of bone should be removed but larger pieces with soft-part attachment may often be left. Instruments should be replaced as soon as contaminated and gloves frequently washed or changed.

During the whole procedure the wound should be gently but profusely irrigated with normal saline solution. The sides of the wound must be retracted and the flow of fluid made to come from the depths of the wound outward lest contamination be washed into the distant areas. That is, the wound is washed out and not in. After the superficial part of the wound has been cleaned the deeper portions must also be explored and débrided. This will often require gentle lifting or moving the bone ends to get at the underlying areas.

Bleeding must be controlled lest hematomata form, offering an excellent medium for the growth of pathogenic organisms.

When there has been delay and the patient comes to the operating room more than eight hours after the injury the operative treatment should be more conservative. The contaminated wound has become an infected wound. In removing devitalized tissue at this stage care must be taken not to excise the zone of resistance and so spread the infection. After 24 hours the operative procedures are limited to removal of foreign material and the establishment of free drainage without tension. Just how much shall be done requires thoughtful judgment, weighing the time element against the amount and character of contamination, local and general condition of the patient, and the location of the fracture.

Restoration of Normal Alignment of Bone Fragments. The next step in the operative procedure is to restore the normal alignment of the bone fragments. This is accomplished by the combined use of traction and manipulation of the bone ends by suitable instruments.

The idea that the reduction of displacement should be delayed until the infection is under control cannot be too strongly condemned. The best time to get accurate or even satisfactory reduction is at the original operative attack. If reduction is delayed until the infection has subsided the tissue of repair will usually prevent proper alignment of fragments. Such late reductions will often start up a quiescent infection.

The reduction of displacement should be carried out after the débridement is completed. Débridement cannot be accomplished thoroughly without shifting the position of the bone ends.

Closure of Wound. There is still a difference of opinion as to the wisdom of

primary closure of the wound after debridement and reduction When successfully carried out it undoubtedly lessens the danger of fresh contamination and simplifies the after care It has been adopted in a great many cases with a high percentage of satisfactory results On the other hand where the wound is not closed there is less tension in the traumatized area and so less interference with blood supply and better control of infection In comparing large series of cases handled by the two methods it seems that, although there is a lower percentage of infection in the cases closed primarily, when infection does occur it is more serious than when the wound is left open In the latter group the infection is more localized and less virulent In the former group there is a higher percentage of widespread infection, sepsis, amputations and death It is safer to leave the wounds open Whenever it is possible without undue tension, the bone should be covered by adjacent muscle

Use of Sera and Drugs The prophylactic use of antitetanic serum has been almost universally adopted The necessity for the use of the sera to combat the gas forming organisms is less since the newer drugs of the sulfonamide group and penicillin have come into use The use of these agents can be made more effective if careful bacteriologic studies can be made Some information as to primary drug treatment can be obtained from smears taken from the original wound Reports on cultures made from the debrided tissue will be of great value At the completion of the operation cultures taken from the wound will show the effectiveness of the debridement All such cultures should be aimed to show both aerobes and anaerobes The effect of the sulfonamide group on the healing of compound fractures has not as yet been definitely established Apparently the systemic use of these drugs is associated with fewer instances of severe spreading infections and bacteriemia The clinical evidence in its local use does not show any decrease in the percentage of local infection When used properly, by insufflating a thin layer over the well debrided surface there seems to be no interference with wound healing but when large amounts are introduced there is definitely more edema with consequent tension and delay in the process of repair As a prophylactic measure the advantages of zinc peroxide in its effect on the anaerobes is outweighed by its tendency to cake and to thus interfere with wound healing Its use is indicated when an anerobic infection has developed [See Chapter 22 for a detailed discussion of chemotherapy —Ed]

Maintenance of Position after Reduction This may be accomplished in several ways The selection of the method will depend on local conditions as well as the experience and preference of the surgeon

1 Splints alone These may be of metal, wood, or plaster of paris

2 Traction and suspension The traction may be applied by adhesive to the skin or through a wire or pin transfixing the bone

3 Traction may be maintained by wires or pins introduced on either side of the fracture and incorporated into circular plaster splints or some form of external metal appliance Fixation is more rigid when two pins are placed on either side of the fracture line

4 Internal fixation by metal plates, screws, and bolts followed by suspension

The successful control of infection as well as the bone repair will depend largely on the rigidity of the immobilization of the bone fragments Frequent shifting of position of these fragments will traumatize the tissue of repair and open up channels for spread of infection It will also impede callus formation Single transverse fractures may sometimes be controlled by splints alone but oblique or comminuted cases will require traction or internal fixation

After-treatment of Wound In the

early operative treatment the attempt has been made to convert a contaminated wound into one which is surgically clean. Subsequent treatment aims to combat the growth of bacteria left behind, and to avoid recontamination and any interference with the local blood supply. Dressings should be changed as infrequently and as gently as possible. Free drainage will avoid internal tension. Let gravity aid venous return and avoid constricting bandages.

Many surgeons favor the use of sodium hypochlorite by the Carrel-Dakin method while others feel that this interferes with callus formation. The local use of zinc peroxide and the different sulfonamide drugs has been mentioned. Separation of the wound surfaces by gauze impregnated with petrolatum allows free drainage with minimum damage to the granulation tissue of repair.

The Orr method involves primary débridement, reduction, and immobilization in circular plaster without change of dressing, except at long intervals. This method is more apt to succeed when a thorough débridement is done within a very few hours and the patient can be carefully watched for any evidence of spreading infection.

Rigid internal fixation followed by suspension avoids any outside constriction and permits early active use of the muscles and neighboring joints. It also allows constant inspection of the wound.

The problems involved in the care of compound fractures require careful examination, thoughtful weighing of all factors, prompt action, careful judgment, and great attention to detail. Each case must be studied on its merits and the general principles applied according to the conditions at hand and the technic available. What should be done in a single case quickly brought to a well-equipped hospital will be quite different from the treatment of a similar case in isolated surroundings or when war conditions or civil catastrophe involve wholesale work by limited personnel.

[For details of procedures in compound fractures, see Chapter 22.—Ed.]

SECTION EIGHT

FRACTURES AND DISLOCATIONS OF FACE

24

Fractures of Facial Bones

George R. Brighton, M.D.

Incidence. The general consensus as to the incidence of fractures of the face places them in the following order of frequency: (1) Fractures of the mandible, (2) fractures of the nose, (3) fractures of the malar bone and zygomatic arch, and (4) fractures of the superior maxilla.

Fractures of the mandible and maxilla are not considered in this discussion but will be noted elsewhere. [See Fractures and Dislocations of Jaws, Chapter 25.—Ed.]

The fractures of the nose will be considered first.

FRACTURES OF NOSE

Anatomy of Nasal Bones

The anatomy of the nasal bones must be considered carefully in order that the contours may be reconstructed not only on the outside but also on the inside of the nose.

The two nasal bones bound the anterior nasal opening above. Each one is a four-sided plate with an outer and an inner surface. The upper end is thick and jagged, articulating with the frontal above and also behind. The anterior border, which articulates with its fellow, is thick above and thin below. When the two bones are in place, the united upper portions of these borders form posteriorly the nasal crest, which articulates with the nasal spine of the frontal, and sometimes with the vertical plate of the ethmoid below it. The posterior border joins the ascending process of the maxilla. The thin lower border, slanting downward and outward, has one or two indentations. The outer surface is broader below than above. It is depressed in the upper third, and has there a foramen for a vein. The extreme upper part of the inner surface is rough to join the frontal. Below this it is smooth where it forms the front of the nasal chamber, the lower part of the inner surface sometimes seems hollowed out. A vertical groove for the nasal nerve ends near the notch in the lower border.

Pathology of Nasal Fractures

Practically all nasal fractures are impacted and compounded and are of two general types.

1. **Vertical Impacted or Depressed Fracture.** This type is usually the result of direct trauma as a result of head-on collisions or automobile accidents in which the nose was struck directly from in front. The bones are fragmented and impacted in varieties of positions. In this type of fracture soft-tissue damage is usually severe. The swelling appears very quickly and makes the underlying bone pathology difficult to ascertain. In this type also we have some deflection of the triangular cartilage and it is also possible to have injury to the perpendicular plate of the ethmoid.

2. **Lateral Impacted Fracture.** This type is caused by the blow being received on the side of the nose either because it was delivered from that angle or the recipient

had time to turn the head away from the oncoming blow There are usually three or four fracture lines Three of them are vertical and the fourth is horizontal and up toward the junction of the nose and forehead This provides two fragments The one on the side away from the impact is deviated outward and the fragment on the side of the impact is deviated upward and impacted under the outer fragment When this occurs there is usually a deviation of the triangular cartilage of the septum and it fre-

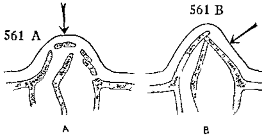


Fig 561 (A) Vertical impacted fracture of nasal bones showing direction of fracturing force and resultant bony deformity, including deviation of nasal septum (B) Lateral impacted fracture, to show direction of force and deformity

quently is deviated away from the site of impact The vomer and perpendicular plate of the ethmoid are not involved unless the blow was very severe

Diagnosis

The diagnosis of fractures of the nasal bones is apt to be very difficult unless the patient is seen immediately after the accident Soft tissue swelling makes the feeling of any fracture difficult and crepitus is almost never elicited X ray examinations made with small dental films will sometimes give the fracture lines There are so many shadows on the x ray films of this region that unless there is considerable deviation from the normal it is easy to make a diagnosis of a fracture when it is not present It is important to observe the septum very carefully when making the diagnosis of a fracture of the nasal bones The presence of hematoma of the septum or a sharp deflection of the septum away from the side of impact may help in making the diagnosis

Treatment

Inasmuch as all fractures of the nasal bones are compounded the greatest care should be taken in cleansing of the nasal passages The presence of sinusitis also adds to the problem of therapy The procedure at the Presbyterian Hospital of New York is as outlined below

If there is any laceration of the skin over the nasal bones the wounds are very carefully cleansed with peroxide of hydrogen and the edges approximated with either silk or dermal sutures If the wound is very large a small twisted drain is inserted at the lower angle Following this procedure the nares are cleansed of clotted blood and debris with peroxide of hydrogen The nasal mucosa is sprayed with a weak cocaine solution (2 per cent) Following this, topical applications of 10 per cent cocaine and adrenalin 1 1,000 are made to the mucous membrane of the turbinates and septum. Under general anesthesia an Ash forceps, the blades of which have been covered with a thin rubber tubing is inserted into the nose, one blade of the forceps on each side of the septum Depending upon the type of impaction, direct or lateral, the forceps are raised upward in the direction opposite to that of the force which caused the fracture In the direct type, if there is not a great deal of comminution, it is possible to feel the edges of the nasal bones re articulate with the nasal process of the superior maxilla and no further manipulation is then necessary If this sensation is not felt the fragments of the nasal bones are molded into position with the fingers when the Ash forceps has broken up the impaction When the reduction is complete the forceps are withdrawn from the nose and any bleeding is controlled by adrenalin or cotton swabs

In our experience at the Presbyterian Hospital we have never felt it necessary to

pack the nose or to use any of the splints designed for internal support. If the septum is returned to normal position it in itself has always seemed sufficient to keep the fragments in position. A light external splint is made of dental plastic and molded over the nose after bleeding has stopped. This is placed in position not so much to act as a support but to act as a protection against dislocation of the fragments by light external trauma.

Most of the cases of simple fracture of the nasal bones following a procedure such as has just been outlined repair very rapidly and without sequelae. However, if there has been considerable infection and osteomyelitis develops it is always possible to resort to chemotherapy and further radical surgery. We have no cases on record in which it was necessary to use the latter additional procedures.

[Prophylactic administration of chemotherapy by mouth is advocated by some men. For use of chemotherapy, see Chapter 22. As a protection against inadvertent trauma from the hands during sleep, splinting of the elbows in extension at night has been advised. This works very well, particularly since a patient with elbows splinted in extension seems to remain consistently on his back during sleep. The necessity for sedative, if the patient is unaccustomed to this position in sleep, is occasional.—Ed.]

FRACTURES OF MALAR AND ZYGOMATIC ARCH

Anatomy

The zygomatic bone (old terminology, malar) lies in the most prominent part of the cheek and is therefore often referred to as the cheek bone. It articulates anteriorly with the zygomatic process of the maxilla, posteriorly with the zygomatic process of the temporal bone, by which junction the zygomatic arch is formed; superiorly it unites with the great wing of the sphenoid and the frontal bone. The anterior-superior portion of the bone forms the lateral orbital border and a portion of the floor of the orbit. In structure the zygomatic bone is compact with little spongy tissue. Assisted by the zygomatic process of the temporal bone, it forms the buttress which supports the maxilla and the lateral wall of the orbit. Beneath the zygomatic arch is the coronoid process of the mandible, an anatomic fact worthy of notice. A depressed fracture of the zygomatic arch or of the zygoma may prevent normal movements of the mandible by mechanical interference.

Pathology of Zygomatic Arch and Malar Fractures

A fracture of these bones is always the result of direct violence; it may be from below, from directly in front, or from above. The fracture may involve the borders of the malar bone alone, but this is very rare. The usual type is that in which the suture lines are disrupted, dislocating the bone upward, downward, or backward. The zygoma may be fractured alone at the malar suture or at the temporal suture. The anterior wall may be driven in by direct violence and the alveolar process broken. The palateal suture may be separated or the malar driven downward and impacted into the maxilla.

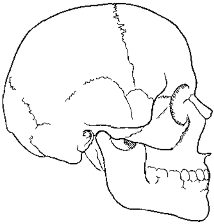
Diagnosis

In examining the fractures of the malar bone or zygoma it is best to have the patient prone, and, standing behind him, to compare the left and right sides of the face digitally and visually, outlining the lower rim of the orbits, the borders of the malars and the zygoma with the fingertips. The lower borders of the malar and zygoma may be examined by hooking the fingertip under it and traveling the entire length of the bone. Any deformity, depression, or mobility with or without crepitus are salient diagnostic points; often the swelling about the orbit may obscure the findings but any definite depression in the inferior border of the orbit immediately suggests displacement

of the malar bone downward and backward Overlapping fragments will produce a palpable ridge When the bone is displaced downward and inward there is a depression of the cheek below the outer canthus of the eye and a bulge below When the displacement is downward and backward there is a depression of the outer half of the inferior orbital ridge and bulging of the zygomatic arch Anesthesia of the lower eyelid upper lip and nose is common due to pressure on the infra orbital nerve In fractures of the malar and zygoma the function of the mandible is rarely interfered with but should always be considered and ruled out as a part of the pathology

In summary the salient symptoms and signs in this condition are

1 Pain
2 Disability
3 Swelling
4 Tenderness
5 Discoloration due to the effused blood reaching the surface In some cases the discoloration may not appear for several days
6 Deformity due to the force and direction causing displacement of the fragments and secondarily to contraction of the muscles attached
7 Abnormal mobility
8 Crepitus
9 X ray evidence of deviation from the normal bony structure



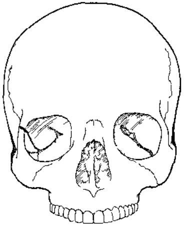


Fig 562 (*Left*) Shaded area shows area and position occupied by malar bone

Fig 563 (*Right*) Malar viewed from in front showing its participation in formation of orbit and its relation to infra orbital nerve When zygomatic arch is broken by a blow from the side and depressed it may embarrass action of lower jaw articulation

Treatment

In the treatment of these fractures the important problem is to restore the normal contour of the bone Early treatment is extremely important as the healing is very rapid in this area and after two weeks it may be almost impossible to reduce the deformity without resorting to operative separation of the fragments The number of methods of reduction of fractures in this region are legion However unless the fracture is a bowing away of the fragments which can be pushed back into place from without all of the methods of treatment must devolve upon the problem of open reduction The following is a description of some of the more common methods of reduction which have been very clearly out

lined by Kanthak in his recent article on this condition.

Matas first proposed the use of wire traction. By his method, described for the treatment of depressed fractures of the zygomatic arch, a large curved Hagedorn needle is threaded with heavy silk and passed through the skin under the zygomatic arch and brought out over the arch. The silk acts as a carrier for a silver wire which is then attached and pulled through to form a wire sling about the bon By this means traction can be exerted ou ward and the bone pulled into position. Th bone is prevented from relapsing to its pr vious position by twisting the wire over glass microscope slide laid over the arch on a piece of iodoform gauze. Other direct approaches have been proposed. Thus, towel clips and cowhorn dental forceps with which to grasp the bone from the outside have been proposed (Manwaring 1913, Gill 1928). Moor-

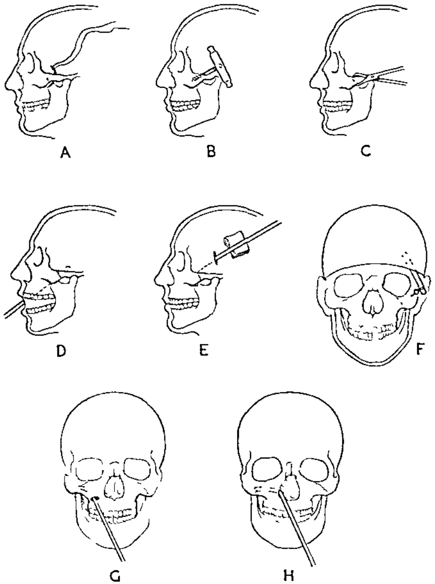


FIG. 564. (A) Matas' method of reduction. (B) Roberts' method. (C) Method advised by Manwaring and Gill. (D) Intra-oral method of Keen. (E) Gillies' method. (F) Method used by Ivy, Curtis and Akerman. (G) Lathrop's method via mucobuccal fold, canine fossa, and antrum. (H) Intranasal method of Shea and Watkins.

head (1917) recommends traction on the bone by a hook or other device passed beneath the depressed bone This method has recently been reintroduced by Patterson (1935) who uses a heavy curved tenaculum passed under the bone through a small skin incision pulling the fragments outward until reduction occurs Similarly Roberts (1928) makes a small incision over the bone and passes a special corkscrew like instrument through the bone and using this as traction manipulates the fragment into place Ivy and Curtis (1931) employ a modification of this method with success They make a skin incision over the depressed bone drill a small hole into the bone and insert either an ordinary screw hook or a dental screw porte into the bone which may be thus man pulated Less direct approaches have been proposed by Lathrop (1906) who makes an incision into the muco buccal fold on the involved side opens the antrum in the canine fossa as through a Caldwell Luc approach cleans the maxillary sinus of bone fragments and blood clots and elevates the depressed malar bone by a sound introduced into the antral cavity Gauze is then packed into the antrum to provide sup port for the fractured bone The pack is re moved in five to ten days Shea (1931) and Watkins (1937) use a similar method of treat ment except that an intranasal antral ap proach is used Keen (1909) recommends reduction by inserting a heavy blunt instru ment under the zygomatic process of the malar bone through the mouth thereby lifting the fragments into place This method has been reintroduced by Straith (1937) Gillies Kilner and Stone (1927) indicated another indirect approach which is a classic of applied anatomy An inch long incision is made in the hairline superiorly and anteriorly to the ear d ssecting down to the temporal fascia through which a small incision is made Through this opening an instrument may now be passed directly downward and forward under the zygomatic bone which can then be levered into a normal position Any and perhaps all of these meth ods suff ce for the treatment of early uncom plicated cases and may be satisfactorily used for here sufficient comminution usually exists to make possible the retention of the fragments once they are elevated Simple elevation of the bones provided they will stay in the re duced position is sufficient to treat the majority of these fractures but some difficulty has been experienced in maintaining the posi tion of the reduced fracture in late or neg lected cases [See also Chapter 25 —Ed]

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25

Fractures of Jaws

Francis S. McCaffrey, D.D.S.

General Considerations. In studying fractures of the maxillary bones and the mandible it will be well to realize from the very beginning that certain of the anatomic features presented will differ considerably from those found in the other bones of the body, and that because of the unusual construction and varied functions of the jaws special methods of treatment are required in the management and repair of jaw fractures.

The presence of the teeth, for example, creates an unusual situation, and their relationship to the fracture may appear at first to be a complicating factor that will interfere with the bone repair. The teeth have no reparative qualities, it is true, and are likely to be a source of infection when lying in the fracture line. Even so, they should not be regarded simply as foreign bodies or as obstacles in the path of treatment. On the contrary, they will serve a very useful purpose. Full advantage should be taken of their presence, because by their location in the dental arches they provide a ready and natural means of anchorage in the reduction and fixation of the fracture. Furthermore, their proper alignment constitutes a main contribution in restoring function, which after all should be the essential motive underlying the treatment of all fractures. The real value of the teeth is indeed strikingly brought home when they are found to be missing, as in edentulous jaws.

Many methods have been devised to control fractures of the jaws and to hold the fragments fixed in proper position during the process of repair. Some of these methods are relatively simple and others are decidedly intricate, but in the final analysis they are all based on three fundamental methods of treatment; namely, fixation by (1) wiring, (2) splinting, and (3) elastic traction.

The many mechanical refinements and modifications employed are simply variations of these basic methods. It will be well to bear in mind that the greater the variation the greater will be the possibility of complicating the case. Too much stress sometimes can be placed on the mechanics of the appliances used to the extent of fostering weakness or promoting inaccuracies. Certain pet theories can be given too much consideration with the possibility of sacrifice of the main issue.

While the mechanical problems involved in the fixation of jaw fractures are of prime importance, and the ingenuity displayed in solving these problems will have a direct bearing on the outcome of the case, it must be remembered that the mechanical skill required is not the chief factor in the management of the injury. The fundamental principles governing the care of all fractures are of major importance, and these principles should be the guiding influence in the selection of the right method of fixation at the right time. Upon this will truly depend the success or failure of the case.

The importance of early treatment, for

example with accurate reduction and control of infection cannot be overemphasized Active early care should always be instituted when not contraindicated by injuries of a more serious character The fracture reduction in the early stages will be far less difficult to accomplish and the possibility of infection will be lessened while delay may spell the difference between a relatively simple case and a complicated one Likewise inadequate treatment in the early stages should be carefully avoided

The improper use of bandages may cause considerable damage by producing increased displacement and an overlapping of the fragments effecting a malocclusion of the teeth resulting in subsequent loss of function Too tight a bandage is worse than no bandage at all

Infection frequently plays an important part in the behavior of the case because of the many possibilities for its development found in the presence of diseased teeth loose fragments of bone foreign bodies and th ompounding of the fracture

The rational extraction of teeth and adequate incision and drainage should be employed not only to control the acute symptoms but also to prevent the continued destruction of bone which may cause a wider separation at the fracture line lead to increased displacement of the parts and result in impaired function

From the foregoing it can be readily seen that up to a certain point the successful treatment of jaw fractures will depend on several factors each one of which will be important in itself but each one of which also will be dependent upon the others The particular ingenuity and skill displayed in planning constructing and applying the methods of fixation must also be supported by a full conception of the processes involved in bone repair together with the ability and knowledge required to control the local complications that may develop The clinically trained dental surgeon will be well qualified to carry on under such circumstances But this is not all Many cases presenting serious general complications caused by multiple injuries or due to systemic diseases that will interfere with the active treatment of the jaw fractures or that will retard the repair of the injury will demand the attention of the physician and surgeon The care of one condition will effect the repair of the other and the situation portrayed will furnish a splendid opportunity for close cooperation on the part of both the medical and the dental practitioner

FRACTURES OF MANDIBLE

The mandible is the largest and strongest single bone of the face but because of its exposed position anatomic formation and lack of rigid support it is also one of the most frequently fractured The fact that it is a vulnerable point in effecting a disturbance of normal equilibrium subjects it to many forms of attack and injury

The body of the bone is horizontal and curved somewhat like a horseshoe the rami are perpendicular and join the body at the back part at nearly right angles This structural arrangement and the presence of teeth (particularly if impacted and diseased) and oftentimes spaces in the dental arch where teeth have been lost contribute to weakness in the bone The articulation with the skull is also an important factor The head of the condyle supported by a thin and narrow neck at the upper margin of the ramus articulates with the glenoid fossa of the temporal bone to form a ginglymo arthrodial joint on each side These two freely moving joints and the bilateral muscular attachments comprise the only support given to the bone and very often this is not sufficient to withstand the violence to which it is subjected These are natural characteristics but they are so pronounced and combine so closely in establishing an inherent weakness in the bone against trauma that fracture should be suspected in all severe injuries to the face and jaw

Due to the size, shape, and suspension of the lower jaw, the fracture may be produced not only by direct violence at the point of injury, but may also occur at some distance from the point of impact due to indirect violence. Hence bilateral fractures are nearly as common as unilateral ones

Causes

In civil life a blow by a fist or some object held in the fist, delivered in a fight or a holdup, is the most common cause, followed in order by automobile accidents, falls, kicks, and various kinds of missiles, including gunshot wounds.

In wartime machine-gun bullets. shell and bomb fragments, flying missiles, and high-speed mechanized equipment will be the major causes, and the injuries more grievous.

The extraction of a tooth rarely causes complete fracture through the body of the bone; the break usually is confined to the alveolar process and is of minor consideration, but when deeply impacted teeth are removed the possibility of fracture is increased and extreme leverage should be carefully avoided.

Classification

Fractures of the mandible are usually classified as to kind, number, direction, and position. Below are listed the therapeutic implications of certain classes of fracture.

Complete or Incomplete. Complete fractures passing through the full substance of the bone are found chiefly in the body of the bone. They are less common in the ramus; here the damage is usually limited to the processes of the bone.

Incomplete fractures usually involve the alveolar process and frequently occur during the extraction of teeth, or when the teeth have been displaced by the violence of injury. Greenstick fractures are occasionally found in children and in the edentulous jaw.

Simple, Compound, and Comminuted. Simple or closed fractures are most likely to be seen passing through the condyloid process of the ramus, through the sigmoid notch, and also, although rarely, through the coronoid process. When there is little or no displacement the repair is rapid and uneventful. It should be remembered that fractures passing behind the angle and involving part of the ramus are not always of the closed variety, being often compounded into the mouth.

Compound fractures appear most frequently in the body of the bone. When the teeth are in the arch, the fracture is always compounded through the gum margin into the mouth, less frequently through the skin. If the jaw is edentulous the fracture may be simple.

Comminuted fractures are quite common in the body of the bone. Comminution may vary in extent, but if the fracture is compounded some sequestration of the bone may be expected, either in the mouth or through the skin. In closed fractures the comminution is less likely to complicate the case, except from the mechanical standpoint.

Single or Multiple. *Single fractures* are the most common at any point in the bone. Double fractures are by no means infrequent. They appear more often on opposite sides of the bone than on the same side, but when on the same side the displacement is likely to be more difficult to control.

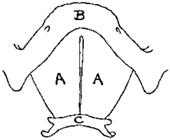
Multiple fractures involving three or more separate regions of the bone are uncommon. Only extreme force will fracture both sides of the body of the bone and both rami at the same time, and even with the present-day hazards of automobile driving and the increase of multiple fractures, fortunately this rarely occurs.

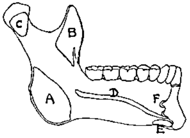
Vertical, Oblique, or Horizontal. These lines are used to describe the general direction of a fracture in its relation to the long axis of the bone although its outline may be very irregular. In comminuted fractures more than one line may have to be men-

tioned to complete the description The oblique fracture is the most common both in the body and in the ramus If oblique fracture lines run in the direction of muscle pull displacement is apt to be marked and difficult to control

Depressor or Elevator One classification of jaw fractures is based on their location in respect to the downward or upward pull of the muscles attached to the bone The action of these muscles may maintain or increase displacement of the parts This classification is therefore significant in plan

the body of the bone the mylohyoid muscle will draw the displaced fragment inward The digastric (anterior belly) and the geniohyoid have closely associated attachments on the inner surface of the mandible at the symphysis and in combination with the mylohyoid pull downward and backward on the forward part of the jaw In single fractures at the symphysis the depressor muscles on each side exercise an equal amount of force and the fragments are likely to remain in good position In single fractures through the body lateral to





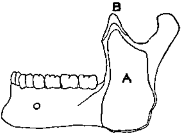


FIG 565 (*Left*) (A) Mylohyoid showing attachment to (B) mandible and (C) hyoid bone It pulls downward inward and backward on body of bone (After Gray)

FIG 566 (*Center*) Inner aspect of mandible showing attachments of internal pterygoid (A) temporal (B) external pterygoid (C) mylohyoid (D) anterior belly of digastric (E) and geniohyoid (F) Internal pteryoid rotates posterior fragment outward on its long axis and pulls it forward External pterygoid rotates condylar head Digastric and geniohyoid pull downward and backward on region of symphysis (After Gray)

FIG 567 (*Right*) Outer aspect of mandible showing masseter (A) and temporal (B) muscle attachments Masseter pulls upward and outward temporal upward and backward (After Gray)

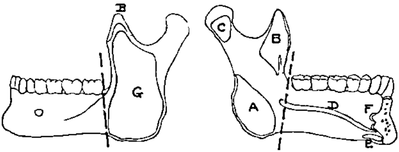
ning treatment Under normal conditions the depressor and elevator muscles acting in groups have a reciprocal action in carrying out the functions of the jaw When a fracture occurs this muscular balance is disturbed Any resultant displacement will be affected by the action of the group exerting the greater pull

THE DEPRESSOR GROUP of muscles is composed of the mylohyoid digastric and geniohyoid all of which have their attachment on the inner surface of the body of the mandible and pass inward downward and backward to the hyoid bone exerting a strong muscular pull in these three directions (Figs 565 and 566) In fractures along

the symphysis this depressor group tends to cause tilting of the fragments or an inward and downward displacement of the chin fragment In bilateral fractures the anterior fragment will be drawn downward and backward into the floor of the mouth being isolated and under complete control of the depressor group As the site of fracture moves backward closer to the angle it will gradually pass out of the range of action of the depressors and become subjected to the upward and outward pull of the elevators In this intermediate situation the action of one group of muscles tends to counterbalance the action of the other group and the parts are held in good anatomic posi

tion. This might be called a neutral zone (Figs. 567 and 568).

THE ELEVATOR GROUP of muscles is composed of the masseter, the temporal, and the internal pterygoid (Fig. 568). The masseter is a short, thick muscle and exerts a strong upward and outward pull on the ramus. The temporal muscle is a broad radiating muscle and exerts an upward and backward pull. The internal pterygoid exerts an upward, inward, and forward pull tending to rotate the posterior fragment outward on its long axis. The external pterygoid, although not an elevator muscle, may act in concert with this group, or independently, to produce displacement. It is a short, thick muscle and pulls the ramus forward and may rotate the head of the condyle in any direction except backward. The combined action of these muscles results in a powerful upward, backward, and outward pull on the ramus, and when a fracture passes through the angle of the mandible the displacement of the posterior fragment may be extreme.



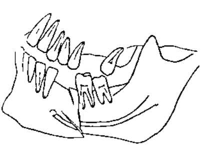


FIG. 568. (*Left* and *Center*) Neutral zone designated by broken line. (A) Internal pterygoid, (B) temporal, (C) external pterygoid, (D) mylohyoid, (E) anterior belly of digastric, (F) geniohyoid, (G) masseter. (After Gray.)
FIG. 569. (*Right*) Showing minor displacement

LOCATION OF FRACTURES

Although any part of the lower jaw is subject to complete fracture, certain regions sustain fracture with greater frequency than others. This serves to establish an order of occurrence which may be outlined as follows.

The highest percentage of fractures occurs at the angle of the mandible. Diminishing in order of frequency are those at the cuspid region, the bicuspid and molar region, the neck of the condyle, the sigmoid notch, the symphysis, the main body of the ramus, and lastly, the coronoid process. The curvature of the bone, the angulation of the rami, and the thinning out of the processes, are, in a great measure, responsible for this order. The various lines of fracture will be noted in the illustrations of reductions reproduced below.

When force is delivered on the exposed anterior portion of the jaw and is met with the resistance of the semi-fixed condylar articulation at the upper extremity of the ramus, which completes the roughly outlined triangle of the mandible, there is a tendency for the bone to buckle on itself, causing fracture through the angle. This region is not considered to be a weak point in the bone because of the heavy external and internal oblique ridges which reinforce it, but, nevertheless, this is where it will break when subjected to stress of this type. Because of the horseshoe shape of the body of the bone, fracture at this point occurs as the result of both direct and indirect violence.

In the cuspid region the body of the bone is in its most exposed position, has only a light protective covering of soft tissue, and is subject to the full force of frontal blows. The bone is sharply curved at this point

and when struck, tends to bend on itself and fracture The cuspid tooth having a long heavy root occupies considerable space in the bone and creates a point of weakness Most fractures through the cuspid region are oblique and pass backward to the bicuspid region The mental foramen is just below and between the first and second bicuspid teeth and it is quite likely that this structure creates another weak point in the bone as does the inferior dental canal passing through its body

In the bicuspid and first and second molar region the bone is flat and less prominent but it will fracture along this area quite frequently It is not well protected by soft tissue and is exposed to the full force of lateral blows

Fracture through the neck of the condyle is usually the result of indirect violence often associated with fracture through some other portion of the bone When the force exerted on the body of the bone exceeds the resistance of the semi fixed position of the head of the condyle in the glenoid fossa the break will occur through the neck of the condyle if the angle does not fracture The bone is comparatively thin and narrow here—an inherent weakness

Fractures passing through the sigmoid notch are produced in similar fashion They extend obliquely backward and downward to the posterior border of the ramus often showing an overlapping displacement

Fractures through the symphysis proper are not common The symphysis, as a fusion point is more heavily calcified than the rest of the bone The fracture occurs to the right or left of the midline where the bone is more porous and extends obliquely away from it

Vertical fractures through the main substance of the ramus extending from the sigmoid notch downward to the angle are infrequent The bone is flat and protected with a heavy covering of muscles in this region, and only violent lateral blows will produce a fracture of this type

The coronoid process is rarely fractured and its displacement will not disturb function It is sometimes associated with fracture of the zygomatic arch in which case the resultant loss of function is caused by the depression of the arch interfering with temporomandibular function

Significant Points in Examination and Diagnosis

The objective symptoms of swelling discoloration, and deformity may be plainly visible, but such symptoms as loss of function, false points of motion crepitus and displacement will have to be demonstrated The subjective symptoms must always be regarded as important

For example pain will be a guiding symptom in determining the site of the fracture It may be present at the point of injury or at a point some distance away If severe it may indicate that the fracture crosses the path of the inferior dental nerve as it passes through the angle or through the body of the bone Any disturbance of this sensory nerve trunk by voluntary or involuntary movement of the parts will increase the intensity of the pain and any unnecessary manipulation of the fragments in this case should be avoided Pain may accompany loss of function at the time of injury but in the ordinary case will be the lesser of the two symptoms Inability to open and close the jaw properly and the induction of pain by any attempt to chew food will sometimes be the first signs of a bone injury This and any disturbance of the bite described by the patient should always be investigated

Swelling at the point of injury is not a positive indication of fracture since the soft tissues may be bruised and inflamed without injury to the bone Swelling located at some distance from the point of injury however, particularly if ecchymosis is present is a very different matter They are definite signs of fracture The swelling may vary considerably Its extent is proportional

to the severity of the injury to the soft tissues and the displacement of the bone fragments, and is increased by the presence of infection The swelling may obscure the true nature and extent of the bone injury, but is of great importance in deciding on the type of treatment indicated and on the role infection is apt to play

Fracture without displacement and not subjected to muscle pull may cause very little disturbance of function, any limitation being due chiefly to discomfort. In tion, and to permit the intake of nourishment.

When a false point of motion is present in the dental arch without displacement of the parts, it may be demonstrated by placing the forefinger of each hand in the mouth on either side of the suspected point of separation while holding the thumbs under the lower border of the body of the bone outside, and then cautiously moving the fragments Care must be taken not to exert immoderate force in carrying out this

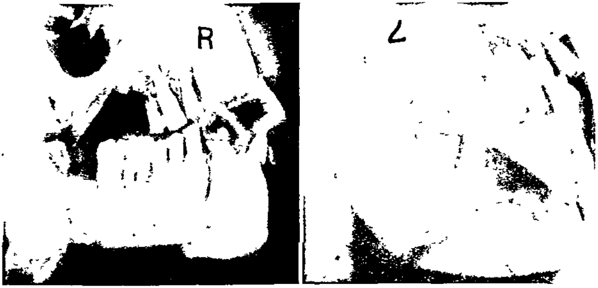


FIG. 570. Marked displacement in comminuted fracture, including depressed central fragment interfering with swallowing.

badly displaced fractures of the body of the bone, especially in the bilateral and multiple type, the exercise of controlled motion of the jaw will be entirely absent, and even the act of swallowing may be extremely difficult. The depressor group of muscles controls the act of swallowing, and their forceful contraction during the act tends to increase the displacement of the fragments. Under such conditions, if the head is held in an upright position, it is equivalent to trying to swallow with the mouth open. When this difficulty is present the prone position, face down or turned to the side, is indicated to offset increased displacement, to give freedom of respira-

examination, because a too vigorous or enthusiastic manipulation may bring about an undesirable displacement and cause unnecessary pain

Displacement

Displacement may range from a minor separation of the fragments, causing only a mild disturbance of the bite (Fig. 569), to an extreme distortion of the parts, resulting in complete loss of function, inability to swallow, and difficulty in breathing and may be associated with laceration of the soft tissues, hemorrhage, and loss of bony structure (Fig. 570)

Once displaced, the jaw will cease to

function as a unit and the separated fragments will be subjected to the divided control of the muscles to which they give attachment The contraction of these muscles will tend to maintain the initial displacement and if the direction of the fracture line permits will actually cause increased separation through voluntary and involuntary movements of the mandible

Fracture through the body of the bone will show increased displacement as the location of the fracture passes backward from the midline through the molar region rather than by muscle pull (Fig 572) Farther back at the angle the fracture passes beyond the range of influence of the depressor group of muscles and enters that of the elevator group There appears to be a neutral zone between these two groups of muscles In this site the counter balancing action of the muscle groups will maintain good anatomic position even though the direction of the fracture line may favor displacement provided that the original violence has not caused a marked displacement (Fig 573) Under these circum

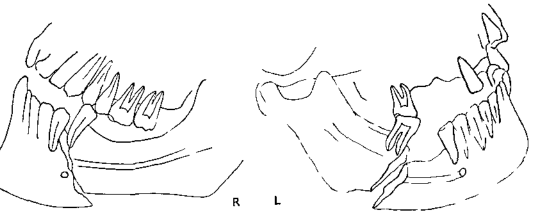


Fig 571 (*Left*) Fracture through bicuspid region with downward displacement of anterior fragment Compare with Fig 572

Fig 572 (*Right*) Fracture through molar region with increase in degree of displacement of anterior fragment as compared with Fig 571

The larger or anterior fragment having a greater area of depressor muscle attachment on its inner surface will be subjected *to a stronger muscular force than the* smaller or posterior fragment Consequently the anterior fragment will be pulled downward and inward while the posterior fragment will remain in normal position under the control of the elevator muscles on that side, particularly if the teeth are present (Fig 571)

In fractures through the molar region if the posterior fragment is displaced inwardly it is usually due to the original violence and the fragment will be held out of position by overlapping of the anterior fragment stances the extraction of a tooth in the line of fracture is advisable to forestall the development of infection but only when it *is certain that the posterior fragment will* not be disturbed by its removal and when it is apparent that the tooth will not be a vital factor in the scheme of reduction and fixation

Back of this neutral point the displacement is very likely to become more complicated The elevator muscles having attachment over a major portion of the surface of the ramus exert an extremely powerful force on the posterior fragment pulling it upward outward and forward (Fig 574) Displacement of this type may

be immediate or progressive, and can be extreme. Bony contact may be lost entirely, or overriding sufficient to prevent proper union may exist (Fig. 575). In such cases the presence of a molar tooth in the posterior fragment will be of inestimable value. It is a natural means of fixation when the fracture is reduced, and the best one. When it will serve this useful purpose it should never be extracted, regardless of the fact that it may be loose and painful, and even show fracture of the root or be in the line of fracture and constitute a potential factor in the development of infection. When there is no tooth in the posterior fragment, or if the tooth has been mistakenly removed, it is said to be out of control, a condition that may lead to difficulty in reduction and fixation.

When it seems possible that the displacement may be progressive, all circumstances favoring this condition should be very carefully regarded, and all possible precautions taken to prevent its occurrence.

When abscess formation occurs, early incision for drainage, either externally or in the mouth, should be resorted to, both to control the infection and to prevent bone destruction. It is this breaking down of bone that destroys contact along the fracture line and allows the posterior fragment to be pulled out of position.

Vertical fracture through the main substance of the ramus is usually splinted by the masseter muscle and will show only moderate displacement (Fig. 576). Fractures through the neck of the condyle and fractures passing obliquely backward through the sigmoid notch are under the control of the elevator muscles and also the external pterygoid. The latter muscle will rotate the head of the condyle, causing a displacement in any one of several directions even to the point of dislocation, while the elevators will pull the ramus upward to produce an overlapping (Fig. 577).

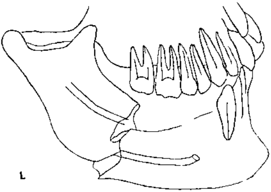
Double and multiple fractures, both unilateral and bilateral, present a somewhat graver problem. The depressor and elevator groups of muscles, pulling in opposite directions, have an opportunity to exert a pull on three or more separate fragments Fracture through the angle on one side and through the cuspid region on the other will result in the ramus being pulled upward by the elevators and in the anterior fragment being pulled downward by the depressors. This is the type of bilateral fracture most frequently seen. If a sufficient number of teeth are in place the reduction and fixation should not be particularly difficult.

FIG. 573. Showing fracture with no displacement due to location of fracture in neutral zone with counterbalancing muscle action.

A more serious problem is found in bilateral fractures through the angle (Fig. 578). Here both sets of elevators and both sets of depressors are in action, and the upward displacement of the rami may be marked. In bilateral fractures through the body of the bone in the bicuspid and molar region, the anterior fragment will collapse downward and backward. There may be some overlapping of the free ends of the bone, but only depressor muscle pull has to

be overcome (Fig 579) However, when this type of fracture is accompanied by fracture through the rami, the added displacement of the intermediate and posterior fragments, together with the collapsed anterior fragment, greatly complicates the case Complete fixation may be extremely difficult to obtain (Fig 580) It may be necessary to resort to some method of delayed reduction Fracture through the neck of the condyle on both sides with an overlapping displacement causes definite func

tures and the displacements to be overcome Both right and left lateral and postero anterior plates should be taken as a routine procedure and these supplemented by localized 'shots' when indicated They should demonstrate existing displacements, indicating the direction of muscle pull to be overcome, they should disclose the position of teeth and fractured roots involved in the line of fracture, determining their relative value for retention close scrutiny will often determine the approximate occlusal rela



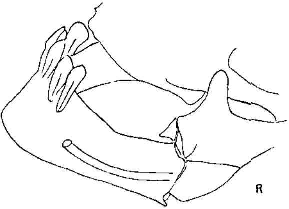


FIG 574 (*Left*) Angle fracture showing upward and forward displacement of posterior fragment

FIG 575 (*Right*) Showing forward and upward displacement of posterior fragment in fracture through angle It was also outwardly displaced There is overriding

tional disturbance The rami are pulled upward by the elevator muscles, causing the back teeth to strike prematurely and producing an opening of the bite in front In order to restore function, the teeth must be brought into occlusion and fixed in this position to close the bite in front regardless of whether or not either of the displaced condylar heads has been completely reduced

X-RAY EXAMINATION

The value of x ray plates lies in the fact that they serve not only to support and confirm the clinical diagnosis, but to augment these findings by revealing the direction and extent of the fracture, and by accurately determining the number of frac-

tionship of the teeth, a very useful factor in securing proper fixation In short, they should not be regarded merely as adjuncts in arriving at a diagnosis, but should be considered important assets in directing the management of the case and very useful guides in directing the forces used in reduction and fixation The most satisfactory x rays are obtained by taking the pictures with the jaw and head in a relaxed position and as close to the normal midline position as the avoidance of superimposition will allow [The excellent discussion of pathology and diagnosis here presented by the author is included because knowledge of the points covered is essential to the planning and carrying out of intelligent treatment —Ed]

Reduction and Fixation

The mandible, being an irregular bone with particular anatomic relationships and articulations, requires special means of treatment when fractured. Nevertheless, it must be borne in mind that the fundamental principles governing the treatment

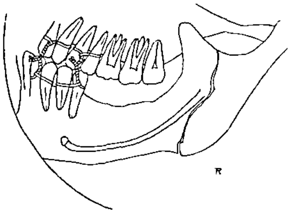


Fig. 576. Due to splinting action of muscles on vertical fracture through ramus there was little original displacement. Wiring is for fixation purposes.

of fractures in general apply in the management of fractures of the mandible, and the so-called special methods found necessary must be so arranged or modified that the treatment will conform with these underlying principles. For example, early reduction of a fracture is of basic importance and should be accomplished whenever possible. Some difficulty may be found, however, in carrying out this principle to the letter in jaw fractures, but in modern hospital practice it should be possible to see the majority of cases early, have the proper equipment at hand and, by selecting a comparatively simple method of fixation, to take advantage of the favorable local reaction presented in the tissues at this time, provided, of course, that there are no general symptoms of a serious nature present to contraindicate local treatment. It is well known that immediately following an injury resulting in fracture the soft tissues involved will be relaxed and there will be a definite numbing sensation in the injured area. The tissues are in a state of localized shock. This condition will last for several hours and during this period the reduction may

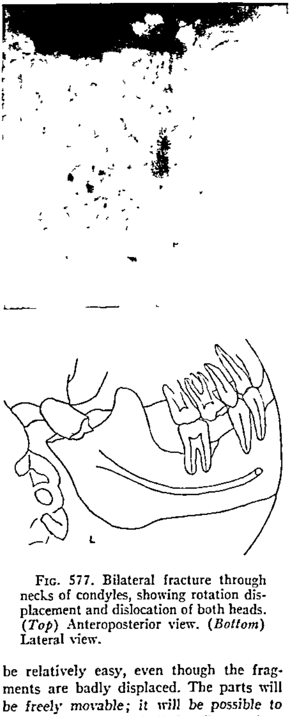


Fig. 577. Bilateral fracture through necks of condyles, showing rotation displacement and dislocation of both heads. *(Top)* Anteroposterior view. *(Bottom)* Lateral view.

be relatively easy, even though the fragments are badly displaced. The parts will be freely movable; it will be possible to manipulate them with little effort and to replace them in normal position without much discomfiture to the patient.

This is the optimum time to institute active treatment Not only is the operation simplified for all concerned but the repair of the lesion will be more rapid In fractures compounded into the mouth the likelihood of infection will be lessened since by bringing the freshly broken ends of the bone together shortly after the injury the fluids from the mouth will be walled off and there will be little opportunity for a well organized blood clot impregnated with mouth bacteria to form between the free ends of the bone to carry infection throughout the fracture line In comminuted fractures the

FIG 578 Bilateral angle fracture showing deformity due to upward displacement of rami

separated fragments are better protected by early reduction retain a greater degree of vitality and have less tendency to sequestrate At no other time during the course of a fracture will a similar condition be presented Deliberate delay should be scrupulously avoided it will only lead to complications and will increase the difficulty of all future operations [This point of view is to be strongly recommended The general principles underlying all fracture treatment are as applicable to jaw fractures as they are to long bone fractures One of the difficulties with the adequate handling of jaw fractures has been that this fact has not been recognized See Chapter 22 for a complete discussion of the general principles underlying fracture treatment —Ed]

As the primary shock of injury subsides sensation returns to the parts a more or less active inflammatory reaction sets in and muscle spasm develops This spasm may be very manifest in the mandible because even the involuntary movements of the jaw in the vital acts of breathing and swallowing will cause increased pain which in turn will produce greater muscular contraction These symptoms become more pronounced as time passes and the reduction meeting with the resistance of the rigid contraction of the muscles attached to the bone will be increasingly difficult If several days are allowed to elapse following the injury it may be found that complete reduction in a single operation is not possible and delayed reduction will have to be attempted thus prolonging the course of treatment

Unfortunately delay cannot be always avoided General symptoms of a critical nature such as skull fractures extreme shock severe hemorrhage and other injuries of a vital character may be present demanding first and immediate treatment Under such circumstances the treatment of the jaw fractures will have to be postponed until the general condition of the patient has improved to a point where there will no longer be any risk in undertaking local treatment

Acute local symptoms alone however should not interfere with the early care of the jaw Lacerations of the soft tissues large swellings inflammation and edema and hemorrhage are not contraindications to reduction Traumatic swellings usually subside quite rapidly following the reduc

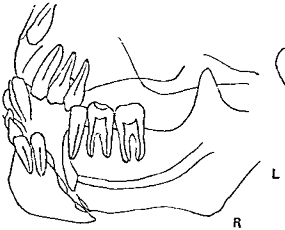
tion of the fracture and ordinary hemorrhage is arrested by pressure and by replacing the bony fragments in proper position. Lacerations of the face, the mucous membrane of the mouth, the gum tissue, and the tongue should be thoroughly cleansed with saline or boric acid, painted with iodine, and sutured. Wounds of moderate size may be completely closed. Extensive external wounds, deep wounds exposing the underlying structures, through-and-through wounds communicating with the mouth, and large ragged wounds should be only partly sutured and some means of drainage established. [See remarks on chemotherapy below.—Ed.]

Every effort should be made to conserve tissue and care should be taken to control infection and prevent the breaking down and loss of tissue structure. Rubber tubes, rubber tissue, and iodoform gauze drains will answer this purpose very well.

After the soft tissues have been cared for, attention can be centered on the treatment of the injuries to the bony structures, and full knowledge of the nature and extent of these injuries should be gained before attempting the final reduction. Ordinarily, x-rays will be helpful, but in cases of severe injuries to the head, jaw, and face truly accurate pictures will be very difficult to secure in the early stages. Normal positions of the head cannot be assumed by the patient and unavoidable superimposition will cloud the readings and tend to be misleading. In this circumstance the clinical signs and symptoms must be greatly relied upon to obtain the necessary data.

It might be well to point out once again that these clinical findings should be sought with as little disturbance to the parts as possible to avoid increased pain and displacement, and also to cite briefly the outline of the examination. The contour of the face is observed to note any structural deformity and the outline of the bone is palpated on both sides from the condyle to the symphysis to locate possible points of fracture. A bulging of the tissues over the temporomandibular joint with pain on local pressure and on movement of the jaw are indications of fracture through the neck of the condyle or the sigmoid notch. If crepitus is detected, the diagnosis is positive. Displacement at the angle may also be felt from the outside but must be confirmed by intra-oral examination.

The dental arch must be inspected for loose and displaced teeth and manipulated for false points of motion by light finger



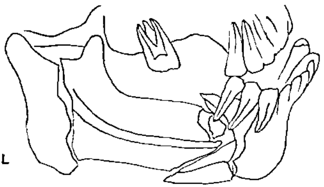


FIG. 579. (*Left*) Showing downward and backward collapse of anterior fragment in bilateral fractures through body of bone.

FIG. 580. (*Right*) Showing effect of complicating ramus fracture with bilateral fractures through body of bone.

pressure In marked deformities of the arch a visual survey will suffice (Fig 581) manipulation will be needed only to learn the extent and direction of the fracture Teeth in the line of fracture that will prove serviceable in holding the parts in place should be saved regardless of the fact that they may become devitalized and act as a direct contributing cause of infection and abscess formation later (Fig 582) Loose teeth having no value in the management of the fracture should be removed (Fig 583) The

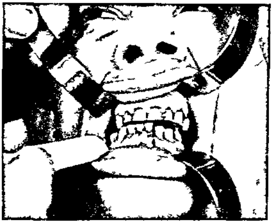


FIG 581 Visual evidence of disturbance of dental arch

position of the teeth and the absence of teeth on both sides of the fracture line must be carefully noted together with the position of the teeth in the upper jaw The occlusal relationship of the teeth must be *studied when the jaws are closed together in unreduced position because in this way* the malocclusion produced by the fracture will be clearly demonstrated and will show to what extent and direction the parts must be moved to restore the occlusion and reduce the fracture

ANESTHESIA

All fractures of the mandible will not require an anesthetic for reduction and fixation Many showing only moderate displacement or passing through the lightly innervated processes of the bone can be reduced without much effort and the operation will not be a painful one In fractures showing marked displacement and requiring considerable manipulation however and in those having a nerve trunk involvement the pain factor will become a major problem particularly after the numbing effect of the injury leaves the parts and it will be necessary to use some type of anesthesia to insure the accuracy of the reduction and the completeness of the fixation When the fracture passes through the angle or the body of the bone and crosses the path of the inferior dental nerve which traverses the deep substance of the bone from the middle of the ramus to the mental foramen the pain is likely to be very severe This sensory nerve is subjected to irritation and trauma from the sharp edges of the displaced fragments and when the parts are moved about in an attempted reduction the pain will increase in intensity and produce an exaggerated muscle pull on the jaw This will add to the difficulty of the reduction and should the pain become exquisite it will also arouse on the part of the patient a defensive resistance that will interfere with the operation and place the result in doubt Regardless of this attempts have been made to reduce this type of fracture without an anesthetic apparently for two unfounded reasons one because the mouth cannot be opened widely enough for the administration of a local anesthetic *which is not true and the other because a general anesthetic supposedly is not indi*cated when the jaws are to be wired tightly together

Local Anesthesia Local or general anesthesia may be employed but in the majority of cases a local anesthetic will be preferable because the patient will need no special preparation the anesthetic can be quickly and easily administered and it will be reasonably effective for fairly long periods of time Al o with the local relief of pain there will be a noticeable degree of muscle

relaxation, allowing freer movement of the parts, which will aid materially in their correct replacement. And, furthermore, the patient can be placed in any desired position, either prone, upright, or even bending forward, to facilitate the reduction. This is very important to consider in overcoming the sigmoid notch in an upward and backward direction to the foramen ovale. The former, or intra-oral method, because of its ease and accuracy of introduction, is preferable whenever the mouth can be opened sufficiently wide to inject the anesthetic, while the external injection is often limited

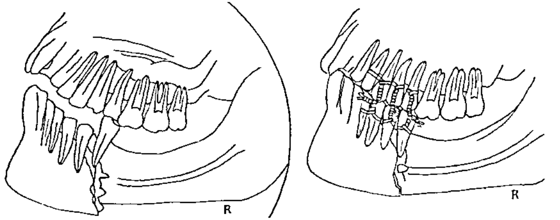


FIG. 582. Showing tooth in fracture line preserved because of value in fixation (*left*), and fixation secured (*right*). This tooth, after fulfilling its primary purpose in fixation, was subsequently extracted.

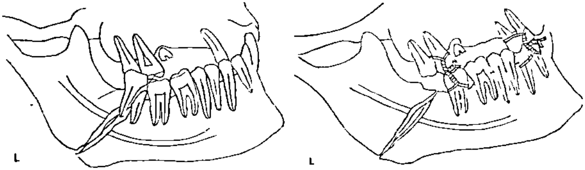


FIG. 583. Showing loose and fractured tooth in line of fracture (*left*). Not essential for fixation. Removed. Fixation secured after removal (*right*).

muscle pull. A 1 to 2 per cent novocaine solution with an adrenalin content of 1 in 5,000 will be very satisfactory for nerve block and infiltration anesthesia. The inferior dental nerve may be blocked in the mouth at the inferior dental foramen on the inner surface of the ramus or externally through the skin at a point under the zygomatic arch to allow the needle to pass through the middle of the space formed by because extensive swelling and edema and distortion of the parts will disguise the landmarks. A novocaine infiltration of the soft tissues around the fracture line will complete the anesthesia. Block anesthesia is effective for an hour or more, and can be repeated if necessary. The patient is conscious, the reflexes are under control, and the after-effects are negligible.

General Anesthesia. General anesthesia,

on the other hand has certain limitations because of the difficulties encountered in its use in jaw fractures The prone position of the patient the forceful elevation of the chin and the labored breathing of lost reflexes will form a perfect combination to increase the depressor muscle pull on the jaw and in fractures showing marked downward and backward displacement of the anterior fragment the reduction will be decidedly more difficult to accomplish and its accuracy sometimes questionable Nevertheless in multiple fractures with extreme displacement requiring a truly forceful reduction or a prolonged manipulation that may result in more or less shock to the patient a general anesthetic will be indicated and the one of choice will be inhalation anesthesia It will be preferable to intravenous or rectal anesthesia because the anesthesia produced by the intravenous injection of a 5 per cent pentothal sodium solution is of relatively short duration may necessitate the injection of an antidote and if *supplemented with oxygen* may interfere with the jaw operation, while avertin (tribromethanol) in rectal anesthesia is not only limited in dosage but may have to be supplemented with nitrous oxide and oxygen or ether Obviously this should place it under secondary consideration and the possible after effects of shallow breathing or lowered respiratory stimulus will definitely contraindicate its use in intermaxillary fixation

Nitrous oxide oxygen ether anesthesia with intranasal tubes will be the most efficient and safest type of general anesthetic to employ The field of operation will be clear and the depth of narcosis can be regulated to conform with the postreduction restraint imposed upon the jaw A suture should be passed through the tip of the tongue and then carried out of the mouth between the teeth after the jaws have been wired together to prevent the tongue from falling back into the throat to block off the air passages If the tongue is very large this may happen anyhow regardless of the tongue suture and as a precautionary measure it is always well to allow the nasal tubes to remain in place until the patient recovers consciousness and to keep them at hand for emergency insertion during the first natural sleep Otherwise it may be necessary *to cut the wires to relieve a sudden* respiratory embarrassment

Fig 584 Barton bandage

Fig 585 Four tailed bandage

Bandages

Several types of jaw and head bandages have been designed to support the jaw and exert traction in the treatment of fractures

Of these the Barton and the modified Barton, using three-inch gauze roller bandages, are the most useful, the former being more stable because of the head wrapping (Fig. 584). They will exert traction in two directions, upward and backward, in the degree desired, and, when properly applied and properly reinforced with adhesive tape, often will maintain sufficient support to prevent increased displacement of the fragments until a more permanent means of fixation can be accomplished.

Four-tailed Bandage (Fig. 585). This bandage is very effective as an emergency measure. It is easily applied over the top and back of the head, and like the Barton exerts traction in two directions, but not with the same amount of control. Any strip of muslin or linen about one yard long and four inches wide will answer the purpose. It is slit down its length from each end toward the center leaving a section three to four inches wide which forms a cup for the chin.

Figure-of-eight, Cravat, and Square or Gibson Bandages. These bandages have very little to recommend them except as quick emergency measures. They do not give adequate support to the jaw and are not very secure.

The Barton or square bandage supplemented by rubber-band attachments on the sides will maintain a more forceful upward pull. Care should be taken not to exert too much pressure since overlapping of the fragments may occur unless the fragments are in complete apposition. The bands are attached by safety pins to the vertical limbs of the bandage over cardboard reinforcements from the temporal regions to the region of the upper part of the angles of the jaw. Tension should be exerted only sufficient to keep the bandage snug. This is important since, in the early stage, too much pressure by bandage will cause increased pressure and edema. This procedure is of value in selected cases where other fixation is precluded because of missing teeth and in cases where circumferential wiring is not practicable.

In the early treatment of fractures any of these bandages can be used to good advantage in supporting the displaced parts, controlling hemorrhage, aiding vital functions, and relieving discomfort. It will limit the free movement of the jaw and keep it at some degree of rest, but it should not be considered as an adequate method of fixation. It is, in reality, only a temporary means of support or may be used as an auxiliary measure to relieve muscle strain. A bandage is by no means strong enough, nor stable enough, to completely counteract muscle pull or prevent displacement of the parts If it is applied too tightly in an effort to accomplish this, it will very likely cause too much pressure for comfort or exert pressure in the wrong direction. When carried around the front of the chin too tightly and heavily reinforced with long strips of adhesive tape, it may serve only to displace the fragments or produce an increased overriding of the parts. Furthermore, too tight a bandage will act as a direct irritating factor causing, through pressure on the soft tissues and pressure of the soft tissues against sharp edges of fractured bone, not only considerable discomfort to the patient, but also increased circulatory stagnation, marked inflammatory reaction, and rapid breaking-down of tissue which, when associated with a compounding of the fracture as so frequently occurs in the jaw, will develop quite promptly into abscess formation.

Only in selected cases will a bandage suffice to hold the jaw in place. This may be observed in fractures showing no initial displacement or so located along the jaw that the equalized action of the depressor and elevator muscle groups will prevent a separation of the parts on movement of the jaw. Also, in certain types of fractures of the mandible in edentulous cases, where the patient's artificial dentures are used as splints instead of some method of wiring,

a bandage may provide sufficient additional support Even in such instances the bandage, although the only means of mechanical support, is not the basic means of fixation In reality the muscles perform this function Properly balanced muscle pull will keep the parts in good anatomic position and in such cases it may be said that the fracture is ' splinted by the muscles '

Methods of Fixation

When the fundamental principles of accurate reduction, the furthering of rapid repair, and control of infection are applied to fractures of the mandible it will be found that there are three basic methods of fixation that may be employed to hold the jaw in place after the fracture has been reduced These are (1) the use of wires, (2) the application of splints and (3) the use of elastic band traction Many refinements modifications and combinations of these basic methods have been introduced to control the various types of fractures that occur, and when these variations are attempted with a reasonable amount of judgment they will be of definite benefit in certain particular cases However, when carried to the extreme they will tend only to complicate the case and possibly retard repair For example in the use of wires for fixation strength in either the wires or the design of application should not be sacrificed for any minor purpose whatsoever, such as opening the jaws for frequent inspection If the wires do not have sufficient strength they will loosen and permit of too much freedom of motion which may interfere with the healing process When splints are employed the maintaining of the accuracy of reduction should not be jeopardized just to maintain a certain degree of function while repair is taking place

As a general rule the best policy to pursue is to select the simplest possible method of fixation that will serve to promote the desired end The exigencies of the case, of course will have a bearing on this selection, and the influence of certain important factors—the element of time, the general condition of the patient, and restraint of function—must be carefully considered All cases are not treated alike, and no one method of fixation should be favored as a routine to the exclusion of another Each one has its particular merits that should be applied to the particular case But even with this in mind it will be found in routine practice that some type of wiring, particularly intermaxillary wiring will be used to a much greater extent and to better advantage than the other methods of splinting or elastic traction It will be more effective than the others in many respects because it is a simpler procedure, it is usually more accurate, and it will save valuable time Wiring will permit of immediate reduction and fixation when the case is first seen or shortly thereafter, which is a distinct advantage, for the early control of the case is often a deciding factor in escaping infection and promoting rapid repair Moreover, the difficulty of taking dental impressions for splints when the mouth cannot be opened properly will not be encountered, and the disturbance of the parts likely to occur and lead to inaccuracy when this is forcefully attempted, together with the loss of time required for the construction of the splint itself will be avoided The method of elastic traction which allows for a certain amount of movement of the parts and which is usually employed in delayed reductions, will not achieve the rigid position so eagerly sought in early and complete fixation

The chief disadvantage of intermaxillary wiring is found in the restraint imposed upon the patient This is of minor consideration in the early stages, but in prolonged cases it must be discontinued or supplemented with some other type of fixation The dental splint will have the advantage of permitting of a certain degree of function during the repair of the fracture and can be kept in place for long periods

of time. It is limited, however, to fractures of the body of the bone and also to fractures with teeth on both sides of the fracture line. Intermaxillary splints have no particular value except in special cases. They necessarily impose the same restraint as intermaxillary wires or will have to depend upon the support of a bandage to hold the parts in place.

Intermaxillary Wiring. By this method the fracture is reduced and the jaws held together in fixed position one against the other by means of wiring the teeth together. It is known as the Gilmer method and with only a few minor modifications it has remained unchanged since it was first introduced. The presence of the teeth and their unique value as a means of anchorage is fully appreciated and utilized. The immovable upper jaw is used as a base against which the movable lower jaw is splinted and held immobilized. The occlusion of the teeth, which acts as a major guide in the reduction of the fracture, is clearly visible to determine the accuracy of position not only during the operation but also through the course of treatment.

The first step to be taken in this method is the selection of the proper teeth to be wired. This is important because upon it will depend the accuracy of the reduction. A study of both the clinical and x-ray findings of the case including principally the location of the fracture, the number of fractures, the amount of displacement and direction of displacement of the fragments, will be necessary. The degree of muscle pull should be carefully estimated and the direction of the force necessary to overcome it closely calculated. The choice is not always a free and easy one to make. The loss of teeth from the dental arches, either previous to or resulting from the injury, will create some difficulty in selecting the teeth. Scattered teeth, malapposed teeth, and diseased teeth may present quite a problem. The pleasant picture of a full complement of evenly placed teeth so frequently used for theoretical demonstration is by no means an habitual occurrence in clinical practice to help simplify the selection of teeth and aid in accommodating the many refinements suggested for wiring.

In selecting the teeth it would be well to first bring the jaws together in the displaced position to show the extent of the malocclusion and the displacement of the parts. An estimate can then be made of how intensively and in which direction the traction must be applied to restore the parts to normal anatomic position. When this is determined the fracture is reduced as completely as possible. The accuracy of the reduction will be aided by the position of certain teeth in each arch which will act as very useful guides in restoring the natural occlusion.

The cuspid teeth, for example, will provide excellent landmarks in this respect. They are relatively stable in position, not subject to drift, and when brought into proper occlusion the direction of the traction required to counteract muscle pull and bring the separated parts into apposition can be more accurately estimated and applied. The teeth of next importance in this regard will be the bicuspids. They lock into occlusion quite accurately but allowance must be made for occasional malposition.

The molars, although they are large and useful teeth, are less reliable because they are always subject to drift when adjoining teeth are missing. The incisors will be very helpful in determining the median line and the abrasive wear of the teeth will be a very useful guide in fitting the teeth together. When the natural occlusion of the teeth has been restored the jaws should be held together by pressure under the lower border of the mandible and the suitable teeth are selected for wiring.

Single teeth or two adjoining teeth may be chosen to carry the individual wires. On occasion more than two adjoining teeth may be used. When adjoining teeth are selected the wire is passed around them in a single loop, or in a figure of eight to obtain greater

stability, particularly if the teeth are not bell-shaped A specific notation of the teeth selected should be made before the wiring is started so as to avoid repeated reductions during the process of the wiring, as it is not always possible to keep the exact teeth in mind while the individual wires are being attached with the mouth open and the jaw returned to its distorted condition As a general rule the wires are fastened to teeth

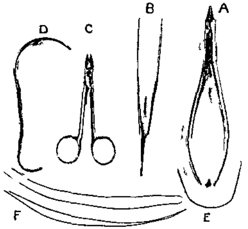


FIG 586 Instruments for intermaxillary wiring (A) Wire forceps (hemostat may be used), (B) thumb forceps without teeth, (C) wire scissors, (D) cheek retractor, (E) single arch bar, (F) Angle s brass ligature wire

as close to the line of fracture as possible, but this is subject to modification to comply with the requirements of traction against muscle pull or to avoid disturbance of diseased or weak teeth

In fractures showing downward and backward displacement of the anterior fragment caused by the depressor muscle, the wires will usually pass around the cuspid and the first bicuspid in the lower jaw and around the cuspid and lateral in the upper jaw to obtain upward and forward traction to counteract the muscle pull In cases of marked depressor displacement wires should be passed around the incisors to augment this and wires should be attached to the second bicuspids and molars to obtain full immobilization In fractures through the angle when the posterior fragment has been displaced upwardly the wires should be slanted in such fashion as to hold the fragments in forceful apposition

The technic of intermaxillary wiring is not at all complicated and few instruments and materials are required (Fig 586) A pair of wire forceps or a heavy hemostat, a pair of wire cutting scissors, a pair of serrated thumb forceps, a cheek retractor, and the wires selected will be all that is necessary Brass wire is most commonly used and is found to be very satisfactory It has sufficient tensile strength to be twisted tightly around the teeth and hold the jaws firmly wired together it is soft and pliant and can be attached to the teeth with less effort than other types of wires which have less flexibility Stainless steel and steel alloy wire is used to some extent but it is not so easily workable as brass wire, nor is it so readily adjustable during the progress of the case Silver wire is not practical for this method, it breaks easily and when used in heavy gauges is too bulky

Angle's brass ligature wire Nos 23 and 24 gauge in strips about 14 inches long is the most suitable Each length of wire can be doubled on itself to give added strength without losing any of its pliability The double wires are pinched tightly together to a point at the bend and smoothed along their length so that they can be easily passed between the teeth above the free margin of the gum and carried around the necks of the teeth selected for wiring in both the upper and lower jaws The free ends of the wires are allowed to protrude from the mouth and are cut off evenly at a length of about two and one half inches The fracture is again reduced, the teeth are brought into occlusion, and while the mandible is held in reduced position by pressure under the lower border the wires in the upper and lower jaws are twisted tightly together to hold the jaws against each other

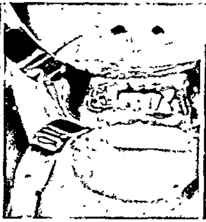


FIG. 587. (*Left*) Showing utilization of anterior teeth to keep bite closed in front.
FIG. 588. (*Center*) Intermaxillary wiring in absence of anterior teeth, showing binding wire.
FIG. 589 (*Right*) Intermaxillary wiring in absence of anterior teeth.

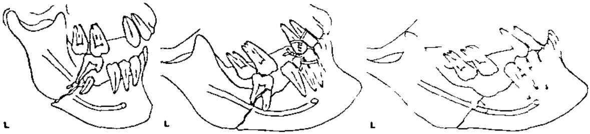


FIG. 590. (*Left*) Fracture through last molar with fracture of root (*Center*) Tooth retained as aid in fixation with intermaxillary wiring. (*Right*) Extraction of fractured tooth after healing.

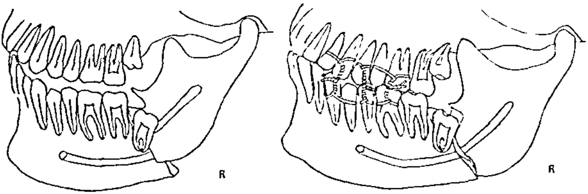


FIG. 591. Fracture through site of impacted molar with characteristic angle fracture displacement (*left*). Tooth retained because it does not, in this type, hold threat of infection or devitalization. Note intermaxillary wiring (*right*).

in fixed position This is a rigid and complete fixation The wires are then cut off short allowing about one quarter inch of free end to be turned in and slanted against the tissue in a way to avoid irritation of the open the mouth by removing these connecting wires without disturbing the wires around the teeth Angle s brass ligature wire is used and when the wires are doubled instead of bringing them tightly together

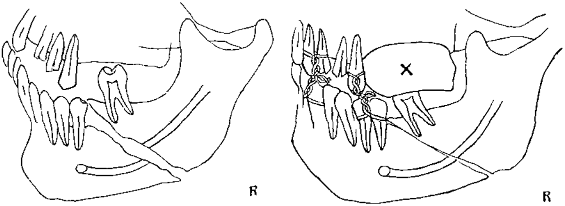


FIG 592 Addition of soft rubber block before intermaxillary wiring to control posterior fragment in presence of edentulous posterior upper jaw (*Left*) Fracture with displacement (*Right*) Wired fracture with block (X) in place between molar of lower jaw and edentulous margin of upper jaw

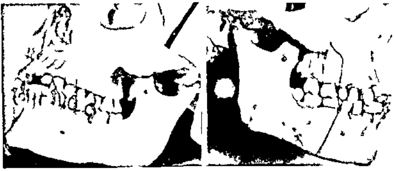


FIG 593 (*Left*) Intermaxillary wiring

FIG 594 (*Right*) Intermaxillary wiring—Ivy loop method Vertical wire is seen passing through loops from between teeth and lower jaw The two ends will be twisted together tightly cut short and turned in against teeth This has already been done with front teeth (See also Fig 595)

lips and the cheeks When this is properly done no protective covering of the wires will be necessary and the mouth can be kept clean with little difficulty (Figs 587, 588, 589, 590, 591 592 593)

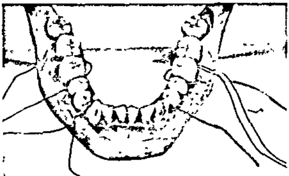
Another type of intermaxillary wiring advocated by Ivy provides loops to which short and connecting wires are attached It has the advantage of making it possible to at the bend a small loop is formed by twisting the wire one or two turns Two adjoining teeth are selected and the free ends of the wires passed around the necks of these teeth in such a fashion as to permit the loops to extend outwardly from between the teeth When the fracture is reduced short connecting wires are passed through these loops to hold the upper and lower jaws

together. This method has certain limitations. It can be used only when adjoining teeth are present and it is not very practical in cases of a close bite. A single thickness of wire is used in this method and in cases of marked displacement and extreme muscle pull the single wire may not prove to be strong enough to hold the jaw in complete fixation (Figs. 594 and 595).

A binding wire will be a very useful addition in fractures showing a tendency to displacement because of depressor muscle pull. The wire is passed across the fracture line and engaged on two or three teeth on each side of the fracture. After the jaws have been wired together this wire is tightened and the fragments held more firmly in apposition.

SINGLE-ARCH BARS (Figs. 596 and 597). When intermaxillary wiring is indicated because the fracture or fractures may be located posterior to the last remaining tooth in the mouth, or the teeth are so scattered as to preclude direct wiring, a heavy bar of half-round wire may be wired to the teeth to provide an attachment for the intermaxillary wires. The bar must be strong and moderately stiff to resist the pull of the connecting wires. German silver Nos. 12 to 14 gauges will prove to be quite practical. Doubled brass wire is passed around the individual teeth and around the bar to hold it in place against the outer surfaces of the teeth. In multiple fractures that also involve the body of the bone this bar will act not only as a splint to control the anterior fracture but also as a very effective adjunct to intermaxillary wiring. Its advantage is found in a lack of complete stability and the possibility of inaccuracy of the reduction when the parts are badly displaced (Fig. 598). This may be overcome by using sectional bars or a combination of the single-arch bar and direct intermaxillary wires. In this manner the fragments may be controlled separately and held in position and a binding wire also added.

In delayed reductions rubber bands may be attached to the bar to obtain the proper traction (Fig. 599). Several types of single-arch bars are available supplied with loops



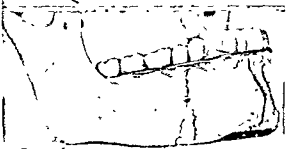


FIG. 595 (*Top*) Circumferential wiring. Left side shows loop method, right side shows direct method.

FIG. 596. (*Bottom*) Single-arch bar wired to lower teeth.

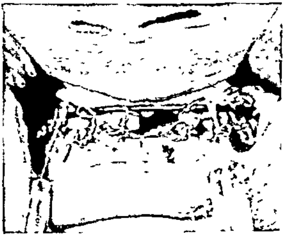


FIG. 597. Single-arch bar wired to upper teeth to support intermaxillary wires.

and hooks to which the connecting wires or rubber bands may be attached. Care should be taken in fitting these bars to the teeth to

prevent the wire loops or hooks from irritating the lips and cheeks and also to avoid bending them so far from the gum margins as to offset the value of the connecting wires

Another point of practical value may be found in utilizing the wires used to fasten the bar in place against the teeth These wires are cut off short about one eighth of an inch or a little longer and turned toward the mucobuccal fold to form hooks These hooks may be used as a base for the intermaxillary fixation together with the bar A very important advantage in the use of a bar is that it can be attached immediately No special preparation is required and there is no time lost in its construction Sometimes impressions are taken and a cast made upon which the bar is formed This is not a necessity the bar can be shaped to the dental arches directly in the mouth

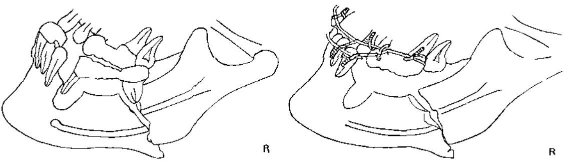


FIG 598 Single arch bars in upper and lower jaws to support intermaxillary wiring Note that reduction by this method is not completely accurate (*Left*) Fracture (*Right*) Reduction

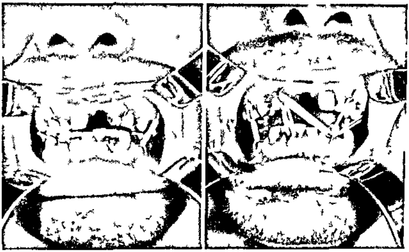


FIG 599 Gradual or delayed reduction by rubber band traction attached through wire hooks about upper and lower teeth

Another striking advantage in the use of a bar is found in severe injuries showing marked displacement of the fragments together with systemic complications such as shock concussion etc in which intermaxillary wiring is contraindicated In such instances the bar can be used as an emergency splint to obtain temporary support even though the reduction is only partial

A bandage applied tightly enough to maintain some degree of reduction in such cases may exert too much pressure and restraint and interfere with the normal functions of breathing and swallowing. When the general condition of the patient has improved the bar may be discontinued and a more suitable means of fixation instituted.

Splints. Theoretically, dental splints, particularly the so-called single-arch cap splints designed by Dr. Hullihen, probably *constitute the ideal means of fixation of* fractures of the mandible (Figs. 600, 601, 602, 603). They not only hold the parts in place but at the same time permit of function. The freedom of motion of the mandible is limited only by the inflammatory reaction and injury to the soft tissues. There is no mechanical restraint; the patient can take nourishment much better, being able actually to chew food; and he has much greater comfort. Furthermore, a splint of this type can be kept in place for long periods of time, extending over several months when necessary, which is invaluable in cases of prolonged infections and loss of bony structure that will regenerate slowly.

Splints may be made of metal, vulcanite rubber, and the acrylic materials which have been lately introduced. Of these the metal splint is probably the best. German silver, or coin silver, either swaged or cast (the former preferred) will be strong, relatively small, thin, and clean. Unfortunately, the cap splint has a distressing limitation. It can be used only in fractures passing *through the body of the bone and not* through the ramus, and it also requires teeth on both sides of the fracture to obtain sufficient anchorage.

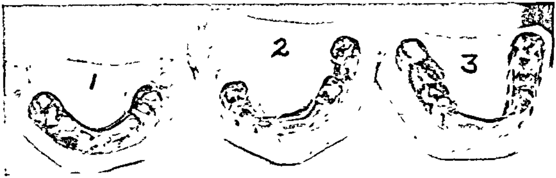


FIG. 600. (*Top*) Three types of single-arch or cap splint. These are cemented to teeth
FIG. 601. (*Bottom*) Single-arch or cap splints on casts from which they are made. Note grinding out of splint over occlusal surfaces to allow accurate contact of teeth of upper and lower jaws.

A certain amount of time will be occupied in the construction of splints. First, impressions of both the upper and lower teeth and the jaws must be taken. This may be done in modeling compound which has been improved quite recently to insure accuracy, but it must be remembered that this exactness may be greatly hindered by the displacement of the parts. From these impressions plaster casts or stone models are made, and any defect portrayed on the

lower arch caused by the fracture must be corrected This is accomplished by cutting the cast through the fracture line and fitting the separated parts into normal occlusion with the teeth in the upper arch If the splint is to be swaged a die and counter die must be made If it is to be cast a wax pattern must be formed and the cast baked All this takes time and with the many operations involved a certain degree of inaccuracy may develop to affect the end result not in respect to the bone repair so much as to the disturbance of function engendered in a change in the occlusion of

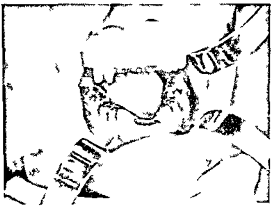


FIG 602 Single arch or cap splint cemented in place

the teeth If this latter is of moderate character it can be improved by spot grinding the teeth to obtain an even bite

When the splint is completed it is fitted to the dental arch after the fracture has been reduced and kept in permanent position by cementing it in place The occlusal surface of the splint should be ground through at interrupted intervals to expose the biting surfaces of the teeth which will act as a guide in determining the natural occlusion The splint should be carried down at least to or slightly over the gum margin A sketchy splint simply forming a narrow band along the teeth will not prove to be very stable particularly if the anchorage on one side of the fracture chances to be weak

Vulcanite splints constructed in a somewhat similar fashion will require considerable bulk to insure sufficient strength The bite cannot be as easily regulated and occasionally they are more difficult to remove when the case is completed

Acrylic splints are bulky in comparison to metal splints but are supposed to have a special advantage and that a doubtful one over both metal and vulcanite splints The acrylic material is transparent and the position of the teeth under the splint can be clearly seen However the splint is not adjustable and any defect in the arch that may be noticed through this transparent material can be corrected only by the construction of a new splint This is of little practical value since in the use of metal splints faulty position may be studied by means of x ray and similarly corrected

The intermaxillary splint also known as the Gunning splint (Fig 604) is designed to hold the jaws together in a manner somewhat similar to intermaxillary wiring Ordinarily it has no particular advantage over the latter but it is usually indicated in cases where a sufficient number of teeth are not available for direct wiring Covering both dental arches and jaws and connecting the splints solidly together creates quite a bulky mass in the mouth and considerable difficulty is found in the intake of nourishment To overcome this the bite is opened in front and a space maintained through which food is passed This feature may tend *to tilt the fragments and disturb the bite* Besides its anchorage is not secure and a bandage must be relied upon to keep it in place Only in selected cases will it have any particular merit Cases showing marked displacement are not suitable for the use of this splint

When sufficient teeth are available separate interdental splints may sometimes be used These splints should be provided with hooks along the sides to which intermaxillary wires are attached The splints in reality double arch cap splints are cemented

in place on the teeth and the wires may be removed at will to relieve the patient when any aggravating symptoms develop (Fig. 604).

The method of providing the single-arch splint with hooks will prove invaluable when the case is complicated by fracture of the upper jaw that will demand later activity of infection and bony-structure loss, the wires may be removed and a splint substituted until regeneration has developed and bony union has been established. Dr. Henry S. Dunning of New York City advocates this method. He has found it to be a very practical one in an unusually extensive experience in the care of jaw fractures. (As regulation of the bite. [See Fracture of Upper Jaw, Chapter 24.—Ed.]

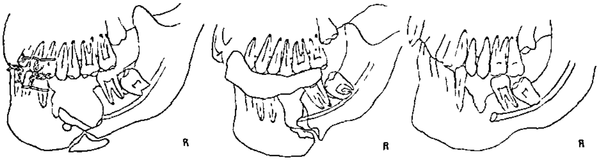


FIG. 603. Fracture with considerable loss of substance. Intermaxillary wiring (*left*), later replaced by single-arch splint (*center*). End-result (*right*). Note bone regeneration.

A very satisfactory procedure to pursue is combining the use of the cap splint with intermaxillary wiring.

The jaws can be wired together for only relatively brief periods of time. Four to six weeks as a rule, and in extreme cases from eight to ten weeks, will be the limit. The time limitation is obvious as far as the intake of nourishment is concerned and, furthermore, the wires, after prolonged attachment, will loosen and allow too much movement, which may delay union if bony loss has taken place due to infection so that frequent adjustments will be required. The wires may weaken and perhaps break and it will be necessary to replace them. Frequent repetition of this becomes extremely burdensome to the patient and the prolonged restraint imposed will add to his discomfort.

In four to six weeks fibrous repair will be established to a sufficient degree to keep the fragments in proper alignment if not subjected to continued positive muscle pull. At this time, if the case has the appearance of being a prolonged affair, because of the

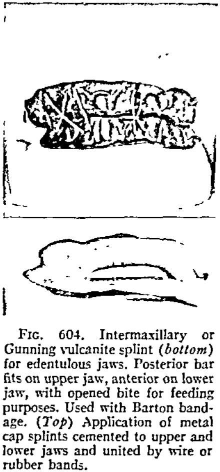


FIG. 604. Intermaxillary or Gunning vulcanite splint (*bottom*) for edentulous jaws. Posterior bar fits on upper jaw, anterior on lower jaw, with opened bite for feeding purposes. Used with Barton bandage. (*Top*) Application of metal cap splints cemented to upper and lower jaws and united by wire or rubber bands.

long as 30 years ago he cited the results in 1,065 cases in "Fracture of the Inferior Maxilla," Jour Amer Med Asso, 64 132 138)

Sectional Splints In fractures presenting a continued marked displacement, or in cases requiring refracture or the breaking up of scar tissue adhesions, sectional splints may be indicated These splints are fashioned to fit the separated parts of the dental arch and are provided with special slot and pin attachments along the outer surface to lock them together Heavy wire hooks or knobs also may be used to answer this purpose

The true anatomic position will depend greatly upon the accuracy with which the stone or plaster casts of the teeth are fitted together to restore the occlusion When the sections of the splint are completed they are cemented in place on the teeth and allowed to set for 24 to 48 hours to obtain sufficient retaining strength The bone fragments must be separated and given complete freedom of movement To accomplish this it may be necessary to cut down on the scar-tissue adhesions and freshen the free ends of the fragments

When the fracture has been compounded into the mouth and teeth are close to or involved in the area of fracture, the approach may be in the mouth and incisions made through the mucous membrane If, of necessity, contamination is to be strictly avoided, the approach is made by incisions through the skin under the lower border of the mandible After the fragments have been brought into proper alignment, which is gauged by the position of the slots on the splint, the sections are locked in position by passing the pin through the slots or winding wires around the hooks or knobs to hold the parts in rigid fixation In some rare instances it may be necessary to combine the lower jaw sectional splints with an upper jaw splint, in which case intermaxillary fixation is obtained

Elastic Traction in Delayed Reduction Delayed reduction may be necessary in cases of extreme displacement and may well be practiced during the early stages of repair While nothing more than a fibrous union exists the fragments may be moved into normal position by properly directed traction provided the muscle pull has not become an uncontrollable factor When this latter problem is present the question arises of whether or not true anatomic position should be sacrificed for function, because to obtain true bony alignment it may be necessary to strip away the muscle attachments which may result in a decided restriction of function Since it is generally accepted that function is the essential motive underlying the treatment of fractures the occasional vainglorious attempt to secure perfect anatomic position may well be misguided

Elastic traction is most suitable for delayed union Individual wire hooks or wire buttons attached to the teeth, single-arch bars, and metal splints provide the anchorage for elastic bands The wire hooks are formed by passing double strands of brass wire around the necks of selected teeth in both the upper and the lower jaws, cutting them off short (about three tenths of an inch), and bending them away from the gum margin to form hooks A single tooth may be chosen but two adjoining teeth will provide greater strength and also prevent the loosening or displacement of the teeth due to the constant pull particularly if there is no occlusal contact

Wire buttons are formed by twisting the short end of the wire into a tight whorl instead of simply bending it into a hook The button will afford a better purchase but has the one disappointing disadvantage of not withstanding frequent adjustment Wire attachments will unfailingly loosen under the strain of the elastic traction and while it is a simple matter to tighten the wire hook and bend it back in place without weakening the wire itself, the loose wire button will have to be unwound before it can be

properly tightened. This is likely to cause breakage and consequent replacement.

Both the single-arch bars and the wires used to fasten them to the teeth will supply the attachments for the rubber bands, while the splints must be supplied with hooks for this purpose. Various special types of metal bands carrying hooks, knobs, etc., have been contrived to furnish the desired attachments, but these occupy too much time in application and are mechanically too intricate to be bothered with. The condition is not an orthodontic problem and should always be considered as a surgical one.

When the intermaxillary rubber bands are first attached, a fair amount of freedom of movement of the jaw should be allowed and the bands so placed as to slowly guide the parts into position. The constant pull of the rubber bands will not only overcome ordinary muscle pull but will overcome the resistance of early fibrous union. During this stage the case should be kept under close observation and both the direction and intensity of the traction carefully regulated. The freedom of movement is gradually restrained and the reduction completed One-half to three-quarters inch size rubber bands, two or three in number, are best adapted to this procedure, and they may be doubled and redoubled in position as the case progresses. Tiny rubber bands exert too much force in the beginning and tend to maintain a single fixed position which will interfere with the directional control of the parts. If immediate and complete reduction is desired, wires will be far more useful in holding the fracture in rigid fixation than a mouthful of small rubber bands.

Circumferential Wiring. When the teeth, which are so valuable in the scheme of fixation, are missing and the jaw is edentulous, or nearly so, added difficulties will be presented in the management of the fracture. When the displacement is moderate and the muscle pull negative, an intermaxillary splint of modeling compound, or the patient's artificial dentures, may be used to hold the parts at rest, while a bandage is applied to obtain a certain degree of fixation. If teeth are present, intermaxillary wires may be used even though only the anterior teeth are available.

With a marked displacement and active muscle pull some forceful means of fixation will be necessary to hold the parts in reduced position in these edentulous jaws This may best be accomplished by passing wires around the body of the bone. A rigid metal splint is first made to fit over the edentulous ridge of the lower jaw with liberal extension on both sides of the fracture line. In cases of bilateral fracture this splint should be carried completely around the arch, and if any teeth are present it should be constructed to fit over the teeth and have an extension carried over the edentulous ridge. This latter type of splint should be cemented in place on the teeth before the wires are passed around the bone, thus providing very satisfactory anchorage.

In passing the wires around the bone, a heavy curved trocar and cannula or a Brophy needle may be employed (Fig. 605). The use of the trocar and cannula simplifies the operation while the Brophy needle first carries a fishline ligature to which the wire is attached and dragged through the soft tissues. The fracture lines must be carefully located and outlined with the parts in reduced position. To judge the position the wires are to take with the fracture in displacement may lead to inaccuracy, because when the fracture is reduced it will show a very different picture and the wires may be found to be in faulty position. The splint should straddle the fracture and the wires should engage each fragment with a liberal margin of contact.

The position of the fracture is more clearly outlined along the alveolar ridge than externally, and to insure further accuracy it is well to pass the instrument from above downward. The mucous membrane in the mouth is pierced by the trocar and cannula

at the selected point on the outer side of the alveolar ridge and carried downward close to the bone to the skin where a small in cision is made to permit its free passage The trocar is withdrawn and a generous length of silver wire No 18 gauge is passed upward through the cannula allowing the free end to extend out of the mouth after which the cannula is withdrawn from the wire The mucous membrane is then pierced sutured and a soft padded bandage applied to relieve muscle strain (Fig 606)

The number of wires passed around the bone will naturally depend upon the num ber of fractures As many as five wires may be used and it is well to remember that when depressor muscle pull is active a wire passed around the bone at the midline will prevent tilting of the splint (Fig 607 608 609)

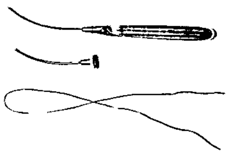


Fig 605 (*Left*) Trocar cannula and wire for circumferential wiring Wire is of silver 18 gauge
Fig 606 (*Right*) Circumferential wiring in situ over metal splint

at a corresponding point on the inner sur face of the ridge and the trocar and cannula carried downward close to the bone and through the skin incision The trocar is again withdrawn and the outside extension of the silver wire passed upward through the cannula to the mouth The cannula is withdrawn and the free ends of the wire ex tending out of the mouth are grasped with heavy hemostats and pulled up close to the bone with a sawing motion Care must be taken not to twist the wire on itself to form a loop at the lower border

This operation is repeated until all the necessary wires are in position whereupon the metal splint is lined with a thin layer of modeling compound and put in place on the alveolar ridge and while the fracture is held in reduced position by pressure under the body of the bone wires are passed over the splint and the free ends of each wire twisted firmly together The incisions are

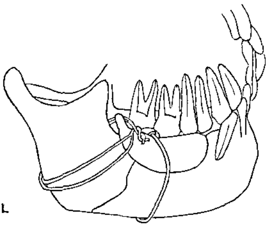


Fig 607 X ray photograph of cir cumferential wire and splint controlling fracture at angle Original position shown in Fig 574

Swelling and edema may be expected as an immediate reaction which rarely goes on to active infection and abscess formation The bandage should be kept not too tight

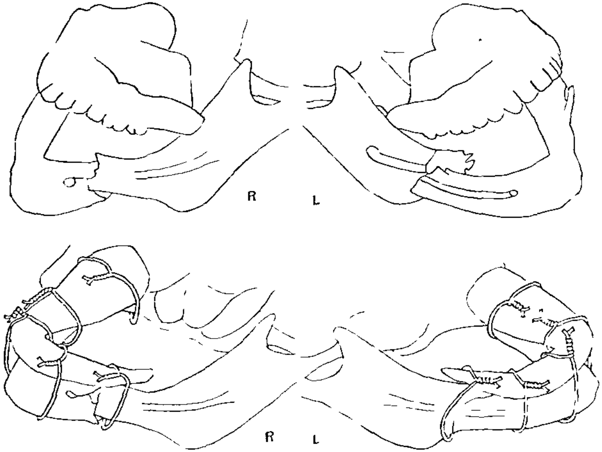


FIG. 608 Bilateral fracture through body of edentulous jaw Circumferential wiring over metal splint (*Top, left*) Right fracture. (*Top, right*) Left fracture. Wired jaw viewed (*bottom, left*) from right, and (*bottom, right*) from left

FIG. 609 Circumferential wiring over metal splint in comminuted fracture of edentulous jaw. Posterior wire has missed separated fragment, a circumstance to be avoided. (*Left*) Original fracture. (*Right*) After wiring.

to prevent irritation and can be discontinued in a week or ten days Liquid diet will be required in the beginning but it may be changed to soft selected diet as the case progresses The wires may be kept in position for 10 or 12 weeks Aside from tightening during the first 10 days they will demand very little adjustment

Circumferential wiring has been attempted with indifferent success to control

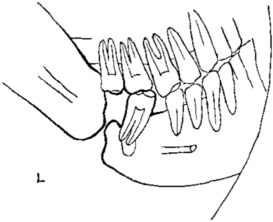


FIG 610 Ununited fracture—result of inadequate fixation

the upward displacement of the posterior fragment in fractures passing through the third molar region and extending backward toward the angle The upward pull of the elevator muscles may be extreme and too powerful to overcome by sheer force and the pressure of the wires and the splint may set up an active tissue irritation with some distressing results Silver wire has also been passed through a hole bored in the heel of the angle and carried backward through an incision in the skin to be attached by heavy elastic bands to a reinforced head cap Even this constant and powerful traction has not been sufficient to overcome the muscle pull It is quite possible for the wire to drag through the hole in the bone and if the effort is to be at all successful it must be attempted shortly after the injury has occurred and before chronic muscle contraction has developed Stripping the masseter muscle attachment away from the bone may relieve some of the muscle strain but quite possibly this may result in restriction or impairment of function

Quite recently external splints have been designed and developed with a high degree of mechanical ingenuity Vitallium and stainless steel metals are used in their construction and they are supplied with screws to engage the bone and universal joints to permit fixation in any desired position They will be helpful when the natural means of support are missing or useless to control the existing displacement Muscle pull may be a disturbing factor and heavy stress should be avoided to prevent the screws from dragging out of position [For the use of multiple pin fixation methods see Chapter 22 – Ed]

Ununited Fractures

Except in cases of substantial loss of bony substance at the time of injury nonunion is not to be expected in fractures of the mandible Ordinarily failure of the fracture to unite is quite rare but when it does occur it is usually the result of faulty reduction strong muscle pull or local infection with bone destruction In fractures passing through the angle if the posterior fragment is drawn upward and outward by uncontrolled muscle pull overlapping will occur and will prevent sufficient contact to obtain bony union This overlapping is also aggravated by infection impacted teeth in the line of fracture and the extraction of a useful tooth in the posterior fragment A heavy fibrous union often develops and if freedom of motion of the jaw and the natural occlusion of the teeth is restored the functional result will be satisfactory

Fractures through the neck of the condyle present a similar condition but they are closed and will repair more rapidly Function will not be greatly disturbed and even though the head of the condyle may be dislocated it is rarely necessary to resort to its removal

Comminuted and multiple fractures passing through the body of the bone may suffer considerable loss of bony structure through infection and the loss of teeth and fail to unite if the gap created is wider than the major thickness of the bone. Syphilis, diabetes, blood dyscrasias, etc., will hamper bone repair, and if not properly treated may go on to nonunion in aggravated cases. It may be that full accord has not been reached regarding the effect of syphilis on fractures in general, but in fractures of the mandible it has been definitely observed that, with a positive Kline or Wassermann, the local symptoms retarding repair will promptly subside when antiluetic treatment is instituted.

When the ununited fracture results in free movement of the fragments with loss of bony substance, marked impairment of function, and nerve-trunk irritation, it will be necessary to resort to bone grafts to correct the defect (Fig. 610). [The technic of osteoperiosteal, cartilaginous, etc , grafts from rib, tibia, or crest of the ilium will be found in Chapter 22.—Ed.]

After-care and Complications

In comparatively mild cases, showing no systemic symptoms or general complications, the after-care is simple routine A good many of these cases are ambulatory or will be so shortly after reduction and fixation have been accomplished. The traumatic swelling and edema may be negligible or will rapidly subside after the jaw is set.

When the jaws are locked together the diet will be restricted to fluids of high vitamin content. Milk, soup, eggnogs, meat and fruit juices, very fine cereals, etc., should be taken frequently during the day. Under the circumstances the patient will be able to take less nourishment at one time, so consequently it should be taken more often. It is never necessary to extract a tooth to permit of the intake of nourishment, for even with a full complement of teeth the passage of fluids can be managed without too much difficulty when the jaw alone is affected. Loss of weight is to be expected during the early stages, but it may be quickly regained before the termination of the case or shortly thereafter.

The mouth is kept clean by regular irrigations or rinses with normal saline or mild antiseptics, and whenever possible by brushing the teeth and appliances with a soft brush.

Adults employed in sedentary occupations may resume their activities, but laborious work should be avoided or modified because increased physical exercise will demand more nourishment than can be supplied under the circumstances. The activities of children and the aged should be restricted because they obviously require more rest.

In closed fractures the wires may be removed in three or four weeks, while in compound fractures the time is extended to from five to seven weeks if active infection has not developed. If an early fibrous union is sufficient to hold the parts in place the patient will improve more rapidly with increased nourishment and moderate exercise until callus formation takes place.

While all cases should be kept under close observation in the early stages to correct changes in position and observe the development of acute symptoms, infection or abscess formation should not be anticipated by incisions through the skin to drain abscesses that do not already exist. Such incisions will close rapidly, or, if kept open with rubber tubes, may render comminuted fragments more susceptible to sequestration. Furthermore, if an abscess does develop, the line of least resistance and therefore of spread may follow another course and further incision will be required

Acute swellings and cellulitis of the soft tissues should be poulticed with hot wet boric-acid dressings. In compound fractures the drainage in the mouth may be sufficient to diminish the swelling, but if an external point of fluctuation is established incision

should be made under and parallel to the lower border of the mandible to secure adequate drainage Rubber tubes are best suited to maintain drainage but rubber tissue may also be used Inadequate drainage will lead to the rapid or continued breaking down of bone and should never be tolerated Loss of bony contact may occur resulting in displacement by uncontrollable muscle pull

In severe injuries with extensive laceration or loss of soft tissue structure and multiple fractures of the jaw emergency measures are first undertaken to control hemorrhage and establish a suitable airway The soft tissues are partially sutured and the wounds dressed with saline or boric acid pads Such injuries are usually associated with general complications which being of a major character should receive first attention Only helpful measures in the treatment of the jaw should be attempted while the patient s condition is critical This may be accomplished by simply supporting the jaw with a bandage by wiring a single arch bar to the teeth or using binding wires to keep the parts from moving freely about and interfering with function

Chemotherapy

In the treatment of jaw fractures the sulfa drugs should be used with a strict regard for the symptoms displayed While the value of their bacteriostatic action is a well established fact *the beneficial effect of* these drugs on fractures undergoing normal repair and in good anatomic position is very questionable

Sulfanilamide sulfathiazole and sulfadiazine are most commonly used at the present time and when given in therapeutic doses of 2 Gm as an initial dose and 1 Gm every four hours until the symptoms subside it should be with the specific purpose of controlling an acute infection which may have developed to complicate the fracture The treatment of the infection will for the moment take precedence over the treatment of the bone injury

In this regard a differentiation always must be made between the traumatic swelling and edema consequent to the injury and an acute cellulitis and abscess formation resulting from a compounding of the fracture and diseased teeth lying in the fracture line Traumatic swelling and edema usually subside quite rapidly during the normal process of repair following reduction and fixation and in such instances even the so called prophylactic doses of the sulfonamides are not indicated

In large external wounds about the jaws the sulfa drugs may be used as a dusting powder to inhibit the growth of bacteria but in the mouth the powdered form will have little or no value because it is quickly washed away by the fluids of the mouth Should gauze drains and packings be employed to keep the drug in contact with the wound they are very likely to act simply as wicks to carry infection from the mouth down along the fracture line to promote pocketing and abscess formation

When the sulfa drugs are given in large doses some alteration in the blood supply to the injured part may take place Diminution of the minute vascular efficiency will tend to retard repair and the wound in the mouth may show a definite clinical change The soft tissues may become dry and shiny and the bone exposed at the fracture line may show a lack of vascular nourishment *Under such conditions the bone may resorb* contact of fragments may be lost and a displacing muscle pull may become effective which may affect the end result [See general discussion of chemotherapy Chapter 22 —Ed]

As soon as the circumstances will permit permanent means of fixation should be employed all possible means should be taken to correct the displacement and restore function, and in prolonged cases all three of the basic methods of fixation may have to be employed

Shock and loss of blood will require special care. Saline infusions, blood transfusions, and the administration of sedatives will be required. Diabetes and epilepsy may have to be kept under control, antiluetic treatment administered, and the patient confined in bed for long periods of time. Under such circumstances it may well be said that the associated efforts of the surgeon, physician, and dental surgeon will reach a peak of service for the best interests of the welfare of the patient.

Fractures of Maxillary Bones

With the exception of the mandible, the maxillae are the largest bones of the face, by their union forming the whole of the upper jaw. Each maxilla is in a fixed position, articulating with nine bones, two of the cranium (the frontal and the ethmoid), and seven of the face (the nasal, the malar, the lacrimal, the turbinate, the palate, the vomer, and its fellow on the opposite side) This anatomic arrangement affords considerable protection against injury and it is only as a result of direct violence that the upper jaw is fractured. Also, because of its size, shape, and position, when fracture does occur it may result in marked disfigurement of the face.

These injuries will vary from incomplete fractures of the alveolar process to comminuted transverse fractures of the maxillae, compounded into the mouth, the sinuses, the nasal cavity, or through the skin. The articulating cranial and facial bones may be involved with extension into the cranial cavity with attending brain injury. The extent of displacement of the parts depends upon the degree of violence. Sudden severe frontal force will cause fracture of the alveolar process, both unilateral and bilateral, with more or less extension into the body of the bone, localized displacement, and injury to the teeth. Extreme frontal force and crushing injuries will drive the maxillae backward toward the base of the skull, causing transverse fractures with downward and, of course, backward displacement, with considerable comminution and impaction of the parts. If the nasal bones and the orbits are involved, the whole face will sag down to the limit of soft-tissue support. Lateral force directed over the malar bone and maxilla will cause radiating fractures of the external antral wall, fracture of the palate, depression of the malar bone into the maxillary sinus, and fracture of the zygomatic arch. Should the fracture be transverse as the result of the lateral force, there will be considerable lateral displacement.

Such injuries as these resulting from sudden or extreme force received in automobile accidents and falls from heights, or from the crushing force of heavy falling objects, heavy missiles, etc., usually cause displacement, distortion, and laceration without loss of tissue, except the teeth. In gunshot wounds and shell, shrapnel, and bomb injuries, however, fractures of the upper jaw are complicated by loss of bone and soft tissue, sometimes to an extreme degree. The point of entry of a bullet may be small and even, with little apparent tissue damage, but its path through the tissues, particularly the bony structures, may be extremely destructive; and at its exit it may carry away large masses of tissue. Shell and bomb fragments, on the other hand, are destructive at the point of contact, the extent of the injury depending upon the force, size, and shape of the fragment.

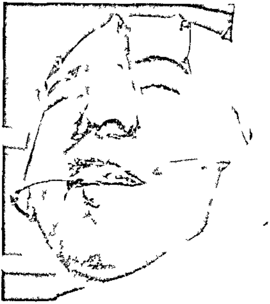
Emergency Treatment

Injuries to the upper jaw are frequently accompanied by hemorrhage and respiratory difficulty. Primary hemorrhage can usually be controlled by pressure. The use of gauze sponges in capillary bleeding will be sufficient, and hemorrhage from the fracture line will be arrested by bringing the parts together and, if possible, holding them in temporary support by the use of bandages. In extensive wounds of the soft parts, the blood vessels may be ruptured and it

may be necessary to clamp the bleeding vessels or soft tissues and use ligatures

Respiratory difficulty may be caused by a blocking off of the nasal passages by displacement of bone or by hemorrhage or it may be produced by fractured and displaced teeth broken dental appliances detached fragments of bone loose foreign bodies lacerated soft tissue and clots of blood filling the mouth and falling back to the throat This material must be removed the nasal passages packed for bleeding and an airway established immediately A suture through the tip of the tongue will keep the tongue from dropping back to the throat to embarrass the breathing and will also assist in keeping the mouth and throat clear A large rubber tube or a metal airway may be passed back to the oral pharynx to aid the respiration Or should the injuries to the mouth and jaws be so severe as to prevent the use of oral tubes nasal catheters may be passed through the nose Care should be taken to guard against recurrence of hemorrhage or blocking of the airway A recurrence may result in death

Restoring the displaced parts to normal position will depend chiefly upon the severity of the injury and the condition of the patient (Fig 611) Lacerations of the soft tissues may be sutured and means for suitable drainage established but in severe cases where the patient is in shock or where there are symptoms of skull fracture or where there has been much loss of blood the replacing of comminuted bone fragments should be limited to the control of local hemorrhage the maintaining of a free airway and the reduction of the patient s pain and discomfort This may be accomplished by the use of binding wires fastened around the remaining teeth and by bandages Foreign bodies if readily accessible may be removed but further manipulation of the parts including the taking of impressions of the jaws for the construction of splints should be postponed until the patient s condition has improved Wide



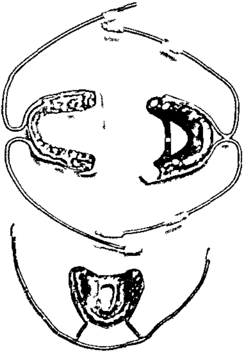


Fig 611 (*Top*) Extent of soft part pathology accompanying upper jaw fractures

Fig 612 (*Bottom*) Types of Kingsley splint

gaping wounds should be cleansed and dressed with saline pads. In certain serious head and jaw injuries, patients will resist all restraint, and will attempt to remove or displace any appliance of fixation placed on the jaws or in the mouth. Under such conditions it would serve no useful purpose to splint the jaws until the acute symptoms have subsided, because their disturbance would tend only to cause increased displacement.

Diagnosis

Minor fractures of the maxillae are, as a rule, not difficult to diagnose A history of the injury, with a careful inspection of the dental arches and a digital examination of the bones of the face, will generally reveal the nature and extent of the injury.

Because of the position of the maxillae, with the anatomic superimposition of the facial bones, clinical signs and symptoms often will be more revealing than the x-rays. Frequently transverse fractures, quite obvious clinically, will not be clearly demonstrated on the x-ray plates. In extensive injuries the problem of complete diagnosis is more difficult, and exhaustive clinical and x-ray examinations should be made. All depressions, displacements, and deviations from the normal should be carefully noted and functional relationships regarded. Fractures through the rim of the orbit, depressed fractures of the zygomatic arch, and depressed fractures of the outer wall of the maxillary sinus will require several x-ray positions to determine the extent of displacement.

Reduction and Fixation

Incomplete fractures involving the alveolar process with displacement of the teeth are readily treated by wiring a bar of half-round wire to the sound teeth, forcing the displaced teeth back into position, and then ligating them to the bar.

Unilateral fractures of the maxilla with displacement of a sizable fragment of bone may be managed by wiring the jaws together with intermaxillary wires. The sound side of the maxilla will keep the mandible fixed against it in normal occlusion, thus causing the opposite side of the lower jaw to hold the fractured fragment of the upper fixed in reduced position.

Transverse fractures of the maxilla vary a great deal in displacement. This may be downward, backward, forward, lateral, or any combination of these. With mild displacement, and no particular disturbance of the occlusion of the teeth, the treatment will consist simply of bringing the jaws together and holding them in position with a Barton bandage reinforced with adhesive tape.

In cases of marked displacement of the maxillary bones, and especially when complicated by fracture of the nasal bones and the palate, it is necessary to obtain upward and forward and, also, occasionally lateral traction.

This is usually successfully accomplished by use of the Kingsley splint (Fig. 612) by means of which the necessary traction for reduction is obtained by passing rubber bands from the lateral arms of the splint upward to a head cap and attaching them in position with safety pins (Fig. 613). The splint is usually made of cast metal and designed to fit over the teeth and gum margins of the upper jaw, with a supporting bar carried across the palate, to prevent bending of the splint. The occlusal surface of the splint is ground down to articulate with the lower teeth (Fig. 614).

If lateral displacement of the fracture of the upper jaw is represented on the cast, as is frequently the case in vertical fractures through the palate, this must be corrected by cutting through the model and adjusting it until normal occlusion is obtained. A strong wire bar is attached to the buccal surface of the splint on each side and carried forward in a curve to pass out of the mouth close to the midline (Fig. 615). If there is laceration of the upper lip, the bars

Fig 613 Kingsley splint with rubber band traction Note various directions of pull designed to correct displacements

gears and crowns of old felt hats A very simple and practical type of head cap may be obtained by using a head bandage reinforced with adhesive tape It is sufficiently stable to withstand the required stress can be adjusted easily and frequently changed The splint may be removed every few days to observe the progress of the reduction together with the occlusal relationship with the lower jaw

Precaution must be taken not to carry the maxillae too far upward out of position by exerting extra strong and constant upward pull It has been found to be far more satisfactory to use fairly light traction in the beginning and gradually increase it until proper stress has been obtained From the nature of the upper jaw fractures and from the principle involved in the use of the Kingsley splint the object of this method cannot very well be directed toward imme

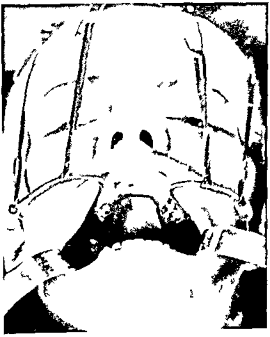


Fig 614 Kingsley splint to show grinding out over occlusal surfaces and bars emerging toward angles of mouth because of upper lip laceration Note absence of palatal bar often used for added strength

will have to emerge nearer the angles of the mouth to avoid disturbance of the laceration as in Fig 614 It is then curved backward on itself to pass along the outer surface of the cheek to the lobe of the ear The splint when put in position in the mouth is not cemented to the teeth but is simply placed on the teeth and held in position by the upward pull of the rubber bands The direction of upward forward or lateral pull is completely controlled by the position of the rubber bands on the lateral arms of the splint

For posterior traction the bands are placed in a posterior position on the bar for anterior traction the bands are placed in an anterior position for forward traction they are slanted forward and for lateral traction they are crossed over the midline

Of the head caps there is a great variety ranging from plaster of paris to leather head

diate complete reduction. Rather, the purpose should be to guide and control the parts in a delayed reduction until they have been brought gradually into good anatomic position and then stabilized until the bones have sufficient anchorage to hold them in place (Fig. 616, 617, 618, 619, 620, 621). This is usually accomplished in about two to four weeks' time.

Well-regulated upward traction will lift and support the sagging tissues of the face when transverse fractures of the maxillae are accompanied by fractures through the nasal fossa and through the orbits. The nasal bones will be held in satisfactory position by the upward pull, and intranasal splints are not, as a rule, required Splints placed in the nose will tend to block off the air passage and cause tissue irritation with subsequent infection.

Fractures passing through the maxillary sinuses are quite common in upper-jaw injuries and do not present a grave problem.

FIG. 616. Multiple fractures of upper and lower jaw.

Ordinarily, the primary hemorrhage is self-limited, and the clotted blood remaining in the sinus will be absorbed, especially if the ventilation is good, which may be aided by shrinking down the membranes with astringents Should active infection develop, it will be necessary to puncture the sinus under the inferior turbinate to establish adequate drainage. Fractures through the ethmoidal and frontal sinuses are of a more serious character and may lead to intracranial involvement because of the close proximity to the brain and possible extension of infection along the venous channels.

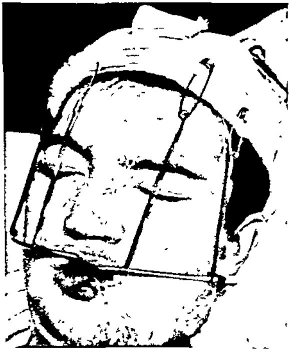


FIG. 615. Kingsley splint with bars *emerging from mouth near midline in* absence of laceration of upper lip.

In badly comminuted fractures, only the completely detached fragments of bone should be removed. The blood supply to the jaws and face is very rich, and considerable conservation of bone and soft tissue is always possible and is of prime importance. Even small pieces of bone having only periosteal attachment should be saved and replaced to avoid a gap in the continuity of the bone and prevent later disfigurement; while the retention of larger fragments containing teeth, although loose and freely

movable will prove invaluable in the scheme of repair

Loss of bony structure and wide separation of the parts will require the use of interrupted or sectional cap splints These should be provided with metal hooks for the attachment of rubber bands and wires to release impacted and control displaced fragments A variety of screw bar and pin and slot attachments have been used to

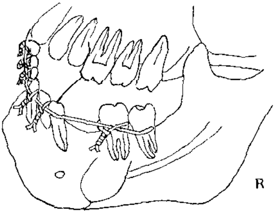


FIG 617 (Same case as Fig 616) Single arch bar to temporarily control fractured lower jaw while splint was being made

obtain the desired result It may be necessary at times to wire sections of the bone with silver wire or better still fine stainless steel wire

Radiating fractures of the external wall of the maxillary sinus with depression of the malar bone and extension through the inferior margin of the orbit are often accompanied by a shattering of the bone with a noticeable disfigurement of the face and will prove to be difficult to manage Reduction by opening through the canine fossa and forcing the parts back into place with a sound has met with only indifferent success The use of bone hooks passed through the skin over the fracture line will be more favorable if the comminution is not too extensive and the fracture not impacted Open reduction may be attempted by making a semilunar incision over the inferior

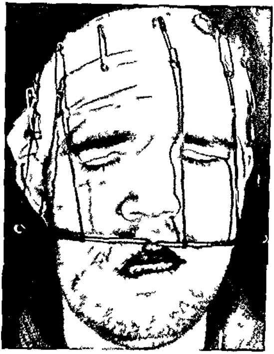
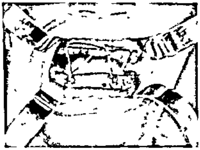


FIG 618 (Same as Fig 616) Kingsley splint to upper jaw and single arch metal splint cemented to lower teeth Note hooks on lower splint for later control of occlusion

FIG 619 (Same case as Fig 616) X ray of Kingsley splint and single arch splint in place Note correction



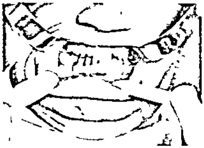


FIG. 620 (*Left*) (Same case as Fig 616) Kingsley splint replaced by single-arch bar on upper jaw. Elastic traction between hooks on single-arch splint on lower jaw and single-arch bar on upper jaw to regain normal occlusion

FIG. 621. (*Center* and *Right*) End-result of case shown in Fig. 616, with restored occlusion and normal jaw function (*Center*) Occlusion (*Right*) Motion range

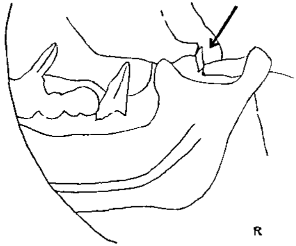
FIG. 622. Titterington's position for x-ray demonstration of fractures of zygoma and malar bones. Depression of zygoma against coronoid process of mandible is clearly shown This interferes with lower-jaw function. Tilt x-ray tube so as to project principal ray about 10° from its usual perpendicular position toward foot of table using five-inch cone, center tube to cassette mounted on 23° angle board. Patient lies prone, head extended, chin resting on lower margin of cassette, nose just off film.

margin of the orbit securing direct vision of the fracture line and reducing the impaction by prying the fragments apart with an elevator

Fractures of the zygomatic arch not only produce a certain amount of disfigurement but also cause loss of function of the mandible The depressed arch of the zygoma will prevent the coronoid process of the mandible from sliding forward in its normal excursion when an attempt is made to open the mouth (Figs 622 623 624) Reduction of this fracture is essential to restore function

The method described by Ivy and originated by Gillies has proved to be very satisfactory An incision is made over the temporal region at a point about 1 cm above the upper margin of the ear and extending obliquely upward and outward It should be about 2 5 to 3 cm in length and carried down to the temporal muscle fascia An elevator like instrument bent at about a 25° angle at the lower quarter or a heavy curved hemostat is passed down along the temporal muscle fascia and under the zygomatic arch The arch is forced outward into normal position thus reducing the fracture No fixation is required once the arch has been sprung into place The wound in the temporal region is sutured (Fig 625)

After a fibrous union has developed in the repair of upper jaw fractures and the splint has been discontinued it will be found occasionally that the occlusion of the teeth has not been completely restored This defect may be corrected by attaching half round wire or wire hooks to the teeth in the upper and lower jaws and then connecting them with intermaxillary rubber bands to slowly draw the upper jaw into normal relationship with the lower If the mandible is fractured in addition splints used for fixation of this bone should be provided with wire hooks for this purpose The repair and proper position of the fracture will not be disturbed by this procedure and it can be accomplished without difficulty before bony union has developed (Figs 616 621)



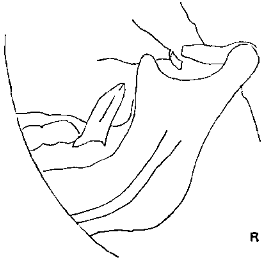


Fig 623 (*Left*) Lateral view showing deformity at site of comminuted fracture of zygomatic arch
Fig 624 (*Right*) Reduction of deformity shown in Fig 623 by method described in text

Function should be the essential idea underlying the treatment of these fractures Careful treatment of the soft tissue wounds early reduction and well planned fixation of the fractures and conservation of the struc

tures will have an important influence on the functional result. Open wounds in the mouth should be irrigated with saline or boric-acid solutions. Adequate drainage must be maintained. This may require in-

FIG. 625. Location of skin incision for reduction of depressed fracture of zygomatic arch.

cision or the removal of sequestrated bone, but under no circumstances should fragments of bone be removed unless completely separated.

Sulfanilamide may be used as a dusting powder in large wounds and also by mouth, 2 Gm., in hemolytic streptococcus infections. In staphylococcus and mixed infections, sulfathiazole may be given by mouth, 2 Gm. as an initial dose and 1 Gm. every four hours day and night until the acute symptoms subside. These drugs have been found to have a beneficial effect in acute infections of the jaws when used in conjunction with surgical drainage. [See general discussion of chemotherapy, Chapter 22 —Ed.]

The destructive force of the blows received, together with the infection encountered, will often result in unavoidable tissue damage and loss in upper-jaw fractures, with subsequent facial disfigurement and impairment of function This is, indeed, unfortunate, but when the primary healing has advanced to its fullest extent and the tissues are clean and free from infection, plastic surgery may be undertaken to correct the defects and restore function.

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SECTION NINE

FRACTURES AND DISLOCATIONS OF TRUNK

26

Injuries to the Spine

Arthur G. Davis, M.D.

Certain generalities bearing on spinal injury have become apparent since the inception of actual reductions 20 years ago. Notwithstanding the ever-present necessity of planning treatment on the individual merits of the case at hand, the following general observations seem important:

1. The centrum of a vertebra forms callus as rapidly as any other osseous structure.

2. The intact posterior arches of vertebrae when hyperextended are capable of sustaining the imposed weight of the torso without the aid of the centrum.

3. Hyperextension with notable exceptions is as important in the reduction of spinal fractures as is straight-line traction in long bones.

4. The tensile strength of the anterior longitudinal ligament is such that a wide margin of safety protects the patient against damage by hyperextension. (See footnote, p. 776.)

5. The anterior longitudinal ligament when interpreted correctly acts as the main reducing medium as well as the main check strap to over-hyperextension.

6. Roentgenography of the posterior arch cannot be depended upon to reveal most fractures and dislocations of this portion. Radiograms of the posterior arch are frequently found to be deceptive and illusory.

7. Because of the impossibility of radiographic exposition of the posterior arch, the factor of horizontal traction during reduction is important as a protection to the posterior arch.

8. Because the status of the posterior arch is unknown, ambulatory treatment is not permitted for six weeks, since the posterior arch takes all the compression strain in hyperextension.

9. Barring demands of unusual cases, ambulatory treatment in constant hyperextension at six weeks is important to induce weight-bearing callus in the centrum.

10. It must be assumed that the damage to the vertebrae is greater, sometimes much greater, than the first radiograms indicate. The immediate spontaneous reaction to hyperflexion is an immediate recoil in extension. In other words, a certain amount of spontaneous reduction frequently takes place in the interval between the moment of injury and the first roentgenography.

11. Visualizing a very definite sequence of steps (including set-up, reduction, adequate fixation, return to function, and final resumption of former occupation) helps to define the detail of and criteria for treatment essential to perfection of the result.

The following aims to classify the spinal injuries ordinarily encountered and outlines sequences for the various classes:

CLASSIFICATION OF SPINAL FRACTURES AND DISLOCATIONS

Compression-fracture Type

1. Thoracolumbar — tenth thoracic to fifth lumbar

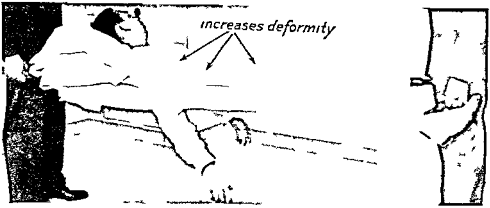


FIG 626 Damaging first aid ordinary attitude in recumbency increase angulation

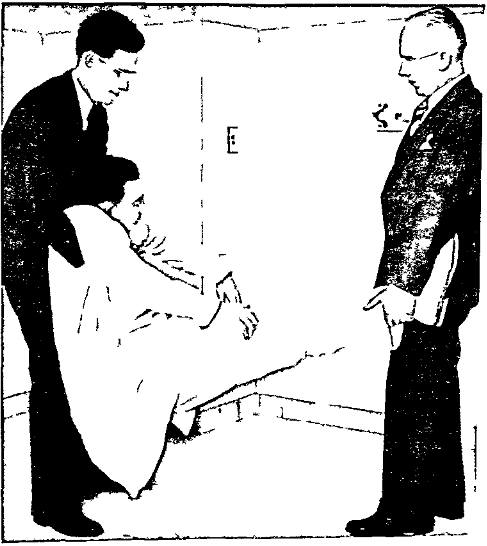


FIG 627 Damaging type of carry opens dislocation increases compression fractures, has caused paralysis

2. Midthoracic—fourth to ninth
3. Upper thoracic—first to fourth
4. Cervical
   a. Third to seventh
   b. First and second

Special Groups
1. Spinous processes
2. Transverse processes
3. Articular processes
4. Laminae
5. Hyperextension fractures
6. Unilateral compression fractures

Dislocations
1. Cervical—unilateral—bilateral
2. Luxations
   a. Cervical
   b. Posterior dislocation of fifth lumbar vertebra

Uncomplicated Crush Fractures from Tenth Thoracic to Fifth Lumbar

This region of the spine, the lower thoracic and entire lumbar region, is more susceptible to fracture than all other parts Statistical data reveal that 75 per cent of all spinal fractures occur within these limits A number of technics besides the one to be described are acceptable, those of Rogers, Dunlop, and Watson-Jones being the most outstanding. The foot-suspension technic has proved most effective as measured by *ease of operation, degree of reduction* and protection of the posterior arch, and comfort of the patient.

FOOT-SUSPENSION TECHNIC

First Aid. Specialized care starts at the site of injury; Figs. 626 and 627 show dangerous handling.

All transfers in the hospital are also guarded. Correct handling is illustrated in Figs. 628 and 629. When the patient is rolled onto the back, a pillow is first placed on the bed or stretcher opposite the fractured vertebra and the patient rolled from prone to supine with a pillow under the fractured region.

Neurologic examination should precede all others. Such examination should include patellar reflexes, heel-cord reflexes, Babinski reflex, and cutaneous sensation covering the areas of the peripheral nerves. Voluntary motions to be tested are dorsiflexion, plantarflexion, inversion and eversion of the foot, and flexion and extension of the knee. If massive paralysis is present, the whole lower extremity should be lifted from the bed and allowed to drop. If an effort, however feeble, is made on the part of the patient to arrest the drop, continuity of the cord must be assumed. If strong pressure posteriorly on the big toe, with the interphalangeal joints flexed, elicits pain, and an effort to withdraw the extremity is exhibited by muscle contraction anywhere from the groin down, continuity is also suggested.

If the cord or cauda equina has been severed or so badly contused as to involve destruction, the above signs are negative and careful study of roentgenograms and the general status of the patient determines whether immediate measures should be applied or definitive treatment postponed. Since it is impossible to decide from the signs whether or not permanent and irreparable damage has been done, the question of immediate reduction of any bony deformity by hyperextension should be considered, for the reason that, if pressure exists, it is important to decompress immediately.

Reduction. A highly efficient set-up ready for reduction is shown in Fig. 630. Several types of commercial fracture tables embodying the mechanics essential to foot suspension are available. Extemporaneous set-ups consisting of an adjustable hammock, a mast or other overhead fastening device, and block and tackle may be improvised. Note in Fig. 631 that the telescoping mast has been opened to full height.

Without anesthesia and usually without opiates, the patient is asked to hold himself from sliding by hanging on to the

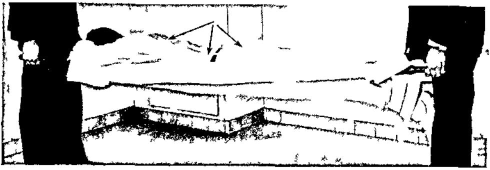


Fig 628 Correct first aid in prone position uses anterior longitudinal ligament as check strap Actually tends to reduce compressions by tensing anterior ligament

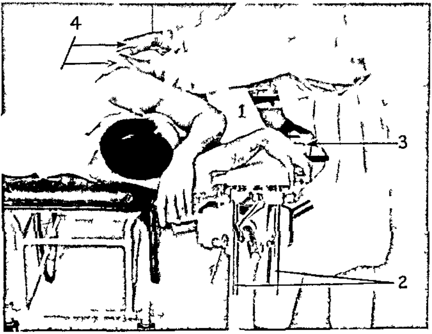


Fig 629 Method of hospital handling Rolling the bundle (1) Canvas hammock in place (2) adjustable rack to raise hammock (3) table leaves in place (4) one hand on shoulder one on buttocks prevents rotation at point of fracture

end of the table. The table leaves are lowered away.

The feet are then simply elevated. The suspension operation occupies but a few seconds. The free end of line is secured. If the thoracolumbar angle is not sufficiently hyperextended, the hammock is then slackened away.

The position is then scrutinized. The criteria of correct position are as follows:

1. Note that the suspension point is fully 12 inches distal to the ankle slings. This insures the factor of horizontal traction so essential to protection of the posterior arch.

2. Note the angle of inclination of the lower extremities; 45° is found to be ideal. Less elevation exerts too little traction on the anterior common ligament More elevation may dangerously compress the posterior arch. In Fig. 631 the open space pictured at the point marked "1," between the anterior spines of the ilium and the hammock, is an index of adequate hyperextension. The width of the span of the hand of open space is a sufficiently accurate gauge of clearance at this point.

3. During foot suspension, the projecting spinous process may be observed or palpated. The prominence disappears during the procedure.

Next a plaster jacket is applied. The jacket is long in front, shorter behind, and well modeled into the lumbar curve. Fig. 632 shows the essentials of a properly applied jacket. Plaster should be well modeled above the crests of the ilia to assure a firm nontelescoping hold on the pelvis. In Fig. 631 the space "1" is awkward to handle. As circular plaster is being applied, turns are alternately made around the torso and through the space. In addition, a plaster slab is introduced and made to fit snugly from the upper limit of the space to the pubic rim. If this detail is planned in advance, no difficulty is experienced. The plaster jacket must reach anteriorly from the sternal notch above to the pubic rim below, posteriorly merely from the lower angles of the scapulae to the gluteal folds.

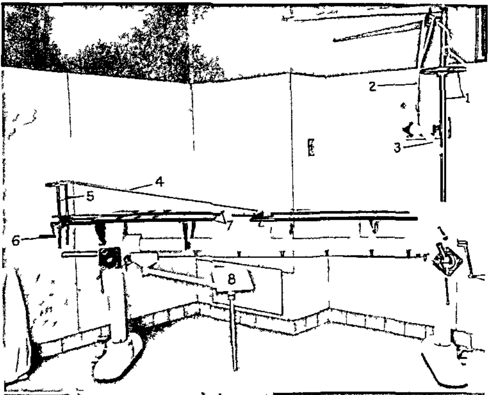
Fifteen to 20 minutes is allowed for the plaster to dry. The hammock is then raised if necessary to permit replacement of the table top. After the leaves are in place, the stretcher is brought alongside, the hammock is slackened away, allowing the chest to rest on the table; the patient is then rolled into the supine position on a pillow, or is shifted in the prone position. Meanwhile, the tackle lowers the legs.

The day following the reduction, a check radiogram determines the degree of reduction. If restoration of vertical height as measured by calipered comparison with the bodies above and below the involved one is insufficient, another manipulation should immediately be considered. Comparison of the original radiogram with those following the manipulation should be made to determine if obstruction to reduction can be detected. If not, re-manipulation is in order, using foot suspension combined with a forward thrust at the level of the involved vertebra, but not directly against the posterior arch. This time, with the feet fully suspended and with more hyperextension than before, a forward thrust is made with thumbs two inches lateral to the midline.

Very rarely is it necessary to re-manipulate. The foot-suspension method, using only gravity with the factors of horizontal traction and hyperextension leverage as described, may be expected to reduce uncomplicated crush fractures of the thoracolumbar region completely.

When the plaster has dried, the table leaves are lifted in place and canvas lengths slackened off. Meanwhile, an assistant operates the block and tackle, exerting more traction if necessary to maintain hyperextension, a pillow or two having already been placed in the bed opposite the point of maximum forward curvature of the cast. Simultaneously, the block and tackle is then slackened off and the patient is rolled

FIG 630



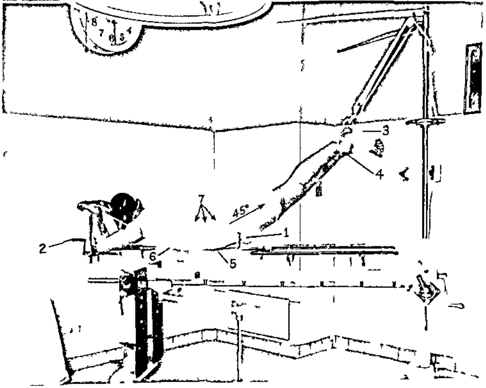


FIG 631

over onto his back, or, if the pillows have not been placed, he is rolled only onto his side in order to preserve the contour of the jacket while the plaster is still green. on his side, or on his back. He may rise to his elbows in the prone position in order to eat, since this merely extends him farther.

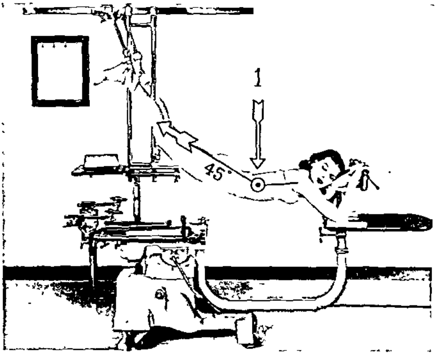


FIG. 631 A. Hyperextension with skin-fitting hammock (1) Indicates hyperextension thrust of levers; 45° movable lever ends in crushed centrum. Upper lever remains relatively unchanged. Ratchet permits any desired degree of hyperextension.

The plaster is then allowed to remain exposed to air for about half an hour to permit evaporation and hardening.

The patient is then instructed to roll about as he pleases, always in the horizontal, never sitting up. He may be face down,

Convalescence. After six weeks of such recumbency in bed, check x-rays are again taken to determine particularly vertical height in the lateral projection. The patient is examined for loss of weight and the question of a new jacket is entertained

FIG. 630. Set-up for uncomplicated thoracolumbar compression fractures. (1) Geared telescoping mast permits quick adjustment of suspension. (2-3) Block and tackle with spreader. By adjusting mast to maximum height, opening block and fall to table level, then using free end of line, the feet are suspended in a few seconds and the free end fastened to the cross bar. (4-5) Hammock and rack adjusted to clear understructure. (6) Crank slackens or tenses canvas hammock. (7) Table top is dropped for jacket application. (8) Cassette holder adjustable to vertical plane for radiogram.

FIG. 631. Typical reduction of uncomplicated thoracolumbar crush fracture. (1) Ample clearance between anterior spines and hammock affords index of adequate hyperextension. (2) Hammock may be lowered with crank to further increase hyperextension. (3) Sheet wadding cushions holder. (4) Holder loop of canvas with ring to suspend. (5) Canvas hammock. (6) Weight of chest carried by hammock. (7) Maximum hyperextension obtained at region involved.

Ordinarily a new jacket is not needed at this time There is ordinarily no weight loss If the jacket has been made of proper *dental plaster its integrity can be depended* upon

The patient is then not only allowed to

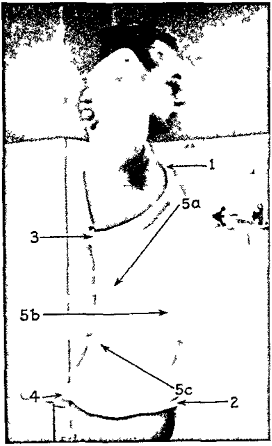


FIG 632 Typical hyperextension ambulatory jacket (1) Top at level of sternal notch (2) bottom at level of pubic crest (3) Posterior top level clears lower angle of scapula (4) posterior bottom level with pubic crest (5 a b c) three point pressure hold guarantees maintenance of hyperextension

be freely ambulatory but is encouraged to walk about as much as possible preferably up to two miles a day as soon as he feels up to this task The object of ambulatory *activity at this time is to induce perpendicular* trabeculations in the callus The vibrational influence of walking serves to induce the necessary trabeculations for unrestricted weight bearing It is not only im*portant to start walking at this time but it* is considered definitely harmful to keep the patient recumbent because as is well known structural trabeculations are the direct result of imposed strain

Few cases exhibit lameness due to the hyperextension Most cases require no physiotherapy other than the rehabilitation of the musculature through ordinary use However where lameness is a feature postural exercises are given to develop the abdominal muscles Obviously the abdominal muscles have been overstretched owing to the hyperextension position The patient is then instructed to sleep on his back with pillows under the knees and to reduce the size of the pillow under the head A piece of plywood is put in between the mattress and the spring to firm the bed somewhat This position allows the abdominals to shorten and the spinal muscles to lengthen The forward curve of the lumbar spine is thus reduced The patient is then given straight leg raising exercises to develop power in the abdominal muscles This with the possibility of the necessity of some massage to the posterior musculature is ordinarily sufficient within a week or two to rehabilitate the patient quite completely

An additional criterion as to the status of the callus in the centrum is that of deep *percussion or thumping over the spinous* process The involved vertebra remains tender to such deep percussion until complete structural restitution has taken place Existence of such tenderness should constitute a sufficient reason to investigate for *detail and continue protection of some kind* whether it be a cast or a brace Ordinarily however such tenderness is not experienced nor does lameness of the musculature persist so that at the end of three months the average patient can go footloose and free *and completely confident of a sound back*

Another technic for the reduction of

thoracolumbar compression fractures is that of Watson-Jones. Fig. 633 shows the set-up, mechanics, and hyperextension obtainable.*

Midthoracic Type

For lack of a better method of delineating this region, it may be described as that part of the prominence of the dorsal curvature contained within the fourth to the ninth thoracic vertebrae. From the standpoint of therapy, special mechanical considerations must be taken into account to attain hyperextension in this region Compared to the thoracolumbar region just described, the midthoracic region is relatively fixed, the leverage component is of greater importance, and there is greater reason for limiting the therapy to the point of fracture

The set-up consists of a low table, two standards to hold the irons, and a pair of Goldthwait irons. Such irons may be made of (1) properly tempered strap iron which can be molded with a pair of wrenches to exert forward pressure in the immediate region of the fractured centrum, or (2) spring steel, and brought together with an adjustable mechanism (Figs. 634 and 635).

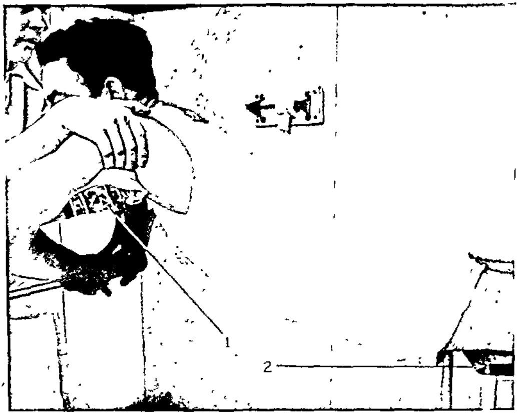


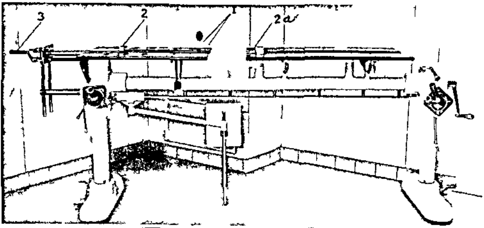
Fig. 633. Watson-Jones technic for reduction of uncomplicated crush fractures (1) Typical operating table being elevated the required amount to support shoulders; (2) stationary table to support thighs.

Where the molded irons are used, a stockinet shirt is first applied, scratchers are introduced fore and aft, and the patient is rolled from the stretcher onto the irons. He holds himself balanced by holding onto the table below and a plaster jacket is applied. It is necessary in using the irons to mold them so that the shoulder girdle and

* A complete description of this technic is contained in Watson-Jones, R., Fractures and Other Bone and Joint Injuries, Baltimore, Williams and Wilkins Co.

head are well below the level of the fractured centrum The component of traction is thus introduced from the summit of the curve of the iron to the head and foot of the patient Care should be exercised to see that such irons are not separated more than two inches from each other otherwise the patient is very uncomfortable because of pressure of the irons against the bony prominence of the ribs Very little difficulty is encountered in attaining complete vertical restoration if the arc of curvature of the irons is sufficient Again there is no need for anesthesia or opiate The recumbent ambu

Fig 634



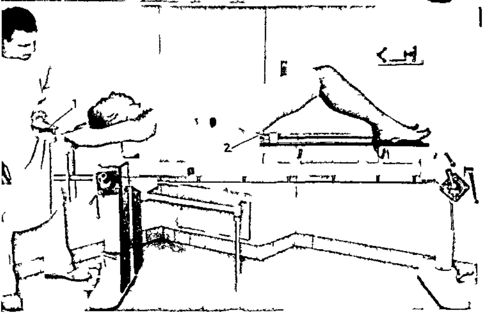


Fig 635

Fig 634 Set up with Goldthwait irons in place (1) ¼ inch spring steel straps —space between straps 2 inches (2 2a) holders for straps (3) crank to adjust curvature of straps

Fig 635 Hyperextension with Goldthwait irons (1) Crank squeezes irons into extension (2) irons

latory, and rehabilitation periods are the same as for the thoracolumbar type.

Upper Thoracic Type

Under this heading again there is reason for therapy designed for the anatomic peculiarities involved. The difficulty at this point is both the difficulty of complete reduction of anterior vertical height and retention of vertical diameter once the vertebra is reduced. The superimposed head and neck tend constantly to move forward so that the head and neck must also be incorporated in the jacket. The set-up consists of the special table depicted in Figs. 636 and 637, in which the hammock is used up to the point of fracture, the head and neck being allowed to droop over an impinging edge.

If such special table is not available, alternate methods may be devised, such as laying the patient over the edge of an ordinary plaster table or over a crossbar mounted on the Goldthwait irons, provided there is free space beyond the end of the crossbar sufficient to allow sagging of the head and neck, or an improvised hammock similar to the one shown mounted on the fracture table may be used (Fig. 630). The advantage of the set-up depicted in Fig. 636 is that, when properly assembled, the procedure is as quickly done as though it were a fracture lower down. For this procedure the *spinous process of the involved centrum must be marked.*

As in the lower spine, the patient again is rolled onto the hammock; a point is chosen three inches lower than the mark. An assistant watches the patient from here on so that there is no shifting or sliding down in the hammock. The mark must always remain clear of the crossbar or point of impingement, otherwise there is the danger of pressure on the spinous process of the involved vertebra. There is also the possibility of destroying the mechanical purpose, since, if the bar were above the marked point, no useful leverage could be expected. A head rest must be supplied whether it be of pillows or other material or as illustrated in Fig. 637. The head and neck must be allowed to fall into extreme extension but only by the gravity force of the head's weight.

A Minerva jacket is then applied. The jacket obviously must reach from the crests of the ilia to the chin. Speed in the application of the plaster may be considerably increased by having a number of plaster slabs made as the circular plaster is being applied. Such plaster slabs pass around the head, if the head is to be included, unite the chest portion with the jaw portion, and can be used as both back and front perpendicular pieces, all of which saves a good deal of the weight of the plaster and is therefore much easier to endure for the long period during which the patient must retain his position.

It is the author's opinion that in this region it is not so important to gain the last increment of vertical height as it is in the more movable sections of the spine, such as the cervical and lumbar, so that if, for example, it is found afterward that there is a 15 to 20 per cent loss of vertical height, it would not be considered important enough to attempt a more drastic method aiming at complete vertical height.

After many attempts at retaining full height of the body in such upper-thoracic compression fractures and having failed in most cases to retain the full reduction, the author is of the opinion that the idea of immediate fusion of the two or three vertebrae involved should be entertained. The inevitable tendency of this section of the spine, bearing as it does the weight of the shoulders and the head, is to gravitate downward and forward. If the Minerva jacket fits closely enough to maintain the last increment of vertical height, it is unbearable to live with. Lateral projections at the time of reduction using the method outlined above have shown complete restoration of vertical height. Several days later,

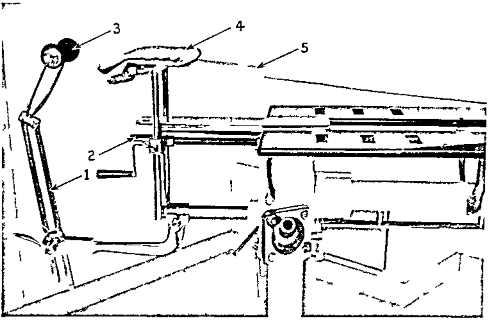


FIG 636 Set up for high thoracic and bilateral cervical dislocation (1) Adjustable mechanism for height and distance from table end (2) tensor crank to adjust hammock (3) head rest (4) blanket or other cushion for hard edge of hammock rack (5) adjustable hammock

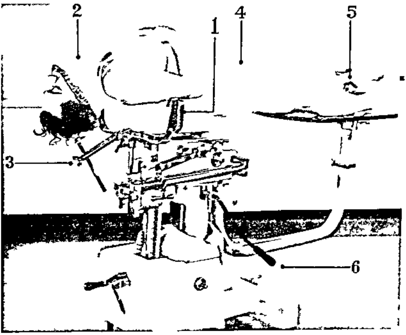


FIG 637 Minerva jacket application for cervical and high thoracic lesions (1) Withdrawable cross bar (2) grooving of plaster for firm hold on mandible (3) head rest permits full hyperextension (4) bottom level of jacket at pubis (5) adjustable hammock (6) adjustable for height

however, it is found that the vertebra has again collapsed. If such collapse represents 25 per cent or more of the vertical height, immediate fusions should be considered because of the threat of a painful spine due to the accompanying distortion of the posterior facets. Much time will thus be saved the patient since his convalescence is not prolonged by the fusion although he must still be fixed in a Minerva jacket. Because of the very limited range of motion in this section of the spine, fusion entails but very little loss of flexibility.

Cervical—Third to Seventh

This region of the spine is very definitely delineated for therapeutic purposes. The medical profession should assume responsibility for the handling of fractures or dislocations of the cervical spine from the time the ambulance service sees the patient through to the time he is fully rehabilitated. Because of the increasing incidence of cervical-spine injuries due to automobiles, the house officers and ambulance attendant need special instruction at the time they begin their service.

The first aider should first grasp the head and exert traction in extension. Others can do the necessary lifting. The patient should be laid supine on the stretcher. One or two ordinary pillows or a folded blanket, sandbag, or folded coat can be placed under the shoulders and neck. The head is thus allowed to sag backward. The patient is then guarded by constant attendance at the head and taken directly into the hospital bed, not to the x-ray room. A temporary halter should be placed around his chin and occiput and five pounds of traction applied. The head of the bed is elevated on 12-inch blocks, the head still remaining in hyperextension. Then a portable x-ray should be taken—a lateral, only, to begin with—in order to locate the area of involvement. Later, if special radiograms are needed through the mouth to show odontoid or high up for first and second cervical fractures, these are taken, but if the involvement is in the region of the fourth, fifth, or sixth, which it commonly is, then a Crutchfield tongs is applied (Figs. 638, 639, 640, and 641). After the tongs are applied, the head can be raised or lowered with a nicety impossible with any but skeletal traction. The introduction of the tongs is completely painless and the control of the head completely effective Meanwhile, a careful neurologic examination will have been made. The procedure thus far has been aimed at the prevention of damage to the cord due to handling.

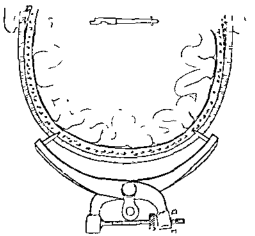


Fig. 638. Tongs are applied transversely to vertex of skull in a vertical plane passing through articulations of cervical spine. Mastoid tips are approximately within this plane and serve as satisfactory landmarks. (Courtesy, W. G. Crutchfield)

It must be realized that, in cervical spines, deformity is probably much greater at the time of the fracture than at the time x-ray is taken. Recoil has already taken place, so that more damage must be assumed than the picture would have us believe. If the head is completely under control, the patient comfortable and relaxed, and the head in adequate hyperextension, most of the reduction already has taken place. For the average case but five pounds of traction is necessary. In occasional cases, up to 45 pounds has been used. The head of

the bed is elevated on 12 inch blocks universally in all cervical spines so as to use the body for countertraction

A simple crush fracture of a cervical spine fractures are treated with infinitely greater delicacy than regions lower in the spine No difficulty whatever has been experienced in simple crush fractures not

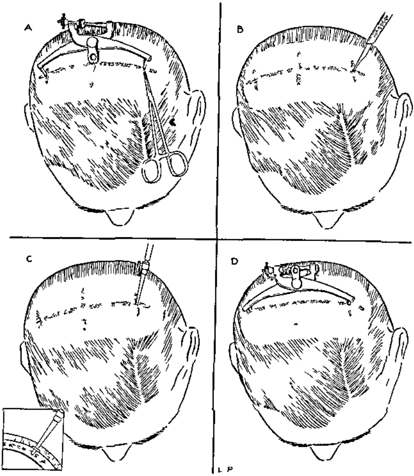


FIG 639 (A) Tongs are designed so traction bar can be used as a guide for correct placement of tong points Traction bar is turned down and placed against scalp with arrow pointing to midline of skull Tong points are then lowered to scalp and points of contact marked with a dye to indicate level of proposed stab wounds (B) Scalp is injected with novocaine, and stab wounds large enough to admit tong points are made down to skull (C-D) Perforations of outer table of skull are prepared by using a small drill point about 2 mm in diameter which is forced to a depth of approximately 3 mm (Courtesy, W G Crutchfield)

vertebra ordinarily reduces itself with this simple tongs traction in hyperextension with, *in the average case*, but five pounds of weight attached Strong arm methods are of no avail and may be damaging Cervical- accompanied by paralysis involving this region The most frequent error seems to be that of insufficient hyperextension One may depend completely upon the anterior longitudinal ligament to prevent over-

hyperextension. (See footnote, p. 776.) The patient simply lies on his back on an air mattress or a sponge-rubber mattress and there is ordinarily no difficulty about the bed care in such cases, since the buttocks

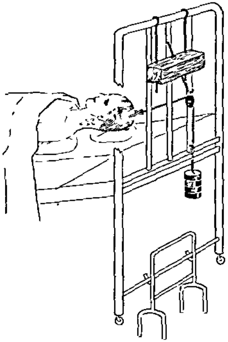


FIG. 640. A special drill point with a fixed guard 3 mm. from the point has been employed to prevent excessive penetration. In average adult skull, this technic should give rise to penetration not deeper than diploe. Greater penetration is usually unnecessary. After openings have been prepared, tong points are fitted into bony perforations and made secure by adjusting thumb screws When tongs are properly locked, points will not bore in. (Courtesy, W. G. Crutchfield.)

can be raised by the patient himself and the torso can be twisted somewhat without disturbing the area of fracture. Position is guaranteed by the skeletal traction. The usual cloth halters passing around the chin and occiput are very distressing, cannot be removed for shaving, usually result in pressure sores, and keep the patient in a constant state of agitation. Crutchfield tongs are a complete answer to uncomplicated cervical fractures. The patient simply remains with the traction applied a sufficient length of time to form fibrous callus.

Several methods of fixation may be used as soon as the fibrous period, approximately three to five weeks, has been reached. Fractures of other parts of the body may make the prompt application of a plaster collar or Minerva jacket awkward. If, for example, a fractured femur exists and traction is in place for such a femur, it may be found preferable from the standpoint of the patient's comfort to await firm callus formation in the femur before the tongs are removed and the plaster jacket is applied. When the time arrives to release the patient from the head traction, two different methods are eligible. A cast including the chin,

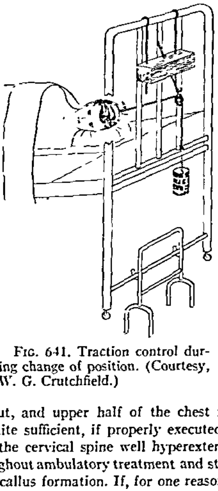


FIG. 641. Traction control during change of position. (Courtesy, W. G. Crutchfield.)

occiput, and upper half of the chest may be quite sufficient, if properly executed, to hold the cervical spine well hyperextended throughout ambulatory treatment and structural callus formation. If, for one reason or another, such a short plaster is deemed inadvisable, then recourse to the long jacket

from the crests of the ilia up to and including the entire head may be applied with the set up as illustrated in Fig 637

If for some extraneous cause (such as internal medical disease or pneumonia) it proves desirable to have the patient ambulatory at a very early date a bivalved plaster collar may be applied (Fig 642)

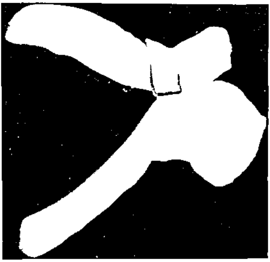


FIG 642 Bivalved plaster collar When bound together on patient and buckled prevents movements in flexion

In this case longitudinal plaques or plaster slabs are laid over a piece of felt which has previously been fitted to the chin neck and chest so as to have a guaranteed hyperextension section in front with the maximum amount of spread between the point of the chin and the chest With this completed the tongs may be removed from the head the anterior shell bound by a bandage around the neck and the patient rolled over prone With the plaster half collar in place the bandage is then removed and a shorter posterior half is made in the same manner over a piece of felt which has already been patterned to fit By means of these two halves bound together with a buckle strap it is possible to maintain complete hyperextension provided accurate fitting and extreme hyperextension have been attained The advantage of the split collar method is that it does not require the removal of a patient to a table or other special apparatus which before fibrous callus has formed would obviously jeopardize the position of the fragments

Convalescence The period of convalescence in fractures of the cervical spine is no different from that in other fractures of the spine Three months is ordinarily the limit of fixation and during the two to four weeks following removal of splintage the necessary physiotherapy is brought to bear to limber the neck muscles Frequently the

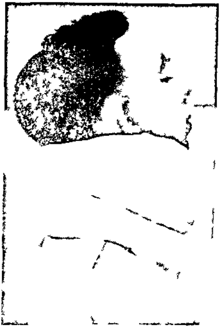


FIG 643 Schantz collar (1) Stockinet 8 inches wide and 6 feet long (2) Filler—12 layers of 8 inch sheet wadding (3) Cotton tape to tie (4) Start under chin wrapping snugly around neck Conform to maintain necessary degree of hyperextension

muscles of the cervical region are painful during the period immediately after the splintage is removed If so a comfortable Schantz collar is applied (Fig 643) In order to make such a collar a piece of

stockinet 72 inches long and 8 inches wide is filled with a dozen layers of sheet wadding of the proper width, the ends stitched, and a piece of tape sewn to one end. The collar is started under the chin, wrapped firmly around and around the neck, and finally tied with the tape.

Cervical—First and Second

Treatment of fractures of the first and second cervical vertebrae is very little different from that for the rest of the cervical spine. However, because of their structural individuality, they must be considered in a separate group. By all odds the most frequent injury at this point is that of dislocation involving the odontoid process and separation of the atlas from the axis. Perhaps the most exacting detail in the case of these two vertebrae is that of roentgenography. Modern high-powered radiographic units demonstrate many more fracture lines in the atlas and the body of the axis than was possible a few years ago when such apparatus was not available. Odontoid fractures are easily shown through the wide open mouth, provided clear detail of the atlanto-axial articulation is shown. Since these joints appear at the same level as the base of the odontoid, when a clear space is shown between the two components of the atlanto-axial articulation, the base of the odontoid and its fracture line will be shown. Lateral detail will show more readily if the odontoid has been displaced forward or backward, but if there is no displacement it may be very difficult to identify a fracture line.

The anteroposterior view is much more dependable. During the anteroposterior roentgenography it is well to place a straight edge from the base of the occiput to the lower margin of the upper teeth. When these points are brought parallel to the straight edge and the straight edge is found to be perpendicular to the plate, the position is optimum to exhibit the odontoid. In the absence of other evidence of fracture or dislocation in the neck and the failure at first to show fault in the first and second cervical, it is well enough to make a second search, particularly if there is persistent muscle spasm because of the difficulty of roentgenography in this region. Recent improvements such as the laminagraph and projections through the foramen magnum may be helpful. Again provided neurologic evidence is lacking, fractures of the first and second cervical are best treated with Crutchfield tongs. The same sequence obtains from the place of the accident to the hospital bed, the halter traction, then the x-ray, then detailed roentgenography and maintenance of traction in hyperextension, except when the odontoid does not seem to come in correct relation to the second because it is found to stay too far backward In this case it may be necessary to eliminate hyperextension, by pulling in a straight line, or even to introduce moderate flexion. This can be done easily with the Crutchfield tongs by simply elevating the traction apparatus.

On account of the great range of mobility between the first and second vertebrae, dislocation is practically always a feature. Fractures involving these two vertebrae are kept in position in bed for a considerably longer period than are crush fractures of the cervical spine. The odontoid has very little to come and go on in the matter of callus formation—the fracture surfaces of the fragments are very limited. The movements of the head very easily can prevent union if the odontoid does not fit accurately (Fig. 643 B).

Fig. 644 visualizes differences in treatment based on the anatomic peculiarities of the region involved.

In Fig. 645, Case E. G., the left illustration visualizes the levers, fulcra, and counteracting pull of hyperextension. The right half of the picture illustrates the complete restoration of form, and especially height, ordinarily attained in pure crush fractures as a result of foot suspension.

Fig. 646 shows a typical reduction with

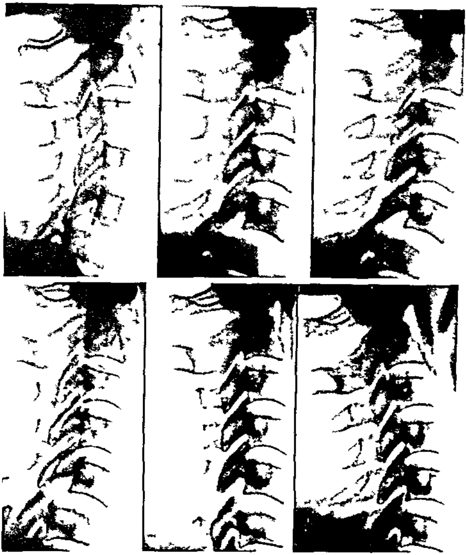


FIG 643 A Reduction with skeletal traction under roentgenographic control this method consists of gradual reduction by proper application of skeletal traction method In cases of bilateral complete dislocations with or without subarachnoid block skeletal traction is applied using 25 pounds of weight pulling in line with vertebra above dislocation Lateral films are taken at 10 minute intervals and it is found that after 20 minutes or more the processes are unlocked At this time head traction is lowered in order to induce hyperextension thus replacing jumped process Traction is then reduced to 8 pounds or less In the case cited author states subarachnoid block was completely relieved (Courtesy Cone and Turner Jour Bone and Joint Surg 19 599)

FIG 643 B. Nonunion of odontoid. (*Top, left*) First roentgenogram following accident showed questionable involvement in fracture (*Top, right*) Two years later, definite nonunion with spasm and occipital radiation. (*Bottom*) Fusion of atlas and axis using wire and osteoperiosteal graft Result—some limitation of motion in nodding but otherwise pain-free Patient returned to his occupation as truck driver.

Goldthwait irons In fractures involving so little compression reductions such as this are easily attained by this method

Fractures of Spinous Processes

Fractures of the spinous processes are of small importance Simple fixation of the region involved with an adhesive cross strap sufficient to guard against the extremes of mobility at the point is ordinarily sufficient If there is sufficient displacement the distal fragment of the process may be removed under local anesthesia

Fractures of Transverse Processes

Contrary to the opinion of a number of contributors transverse processes should be thoroughly immobilized until x ray evidence of callus is present Fractures practically always occur in the lumbar region and due to contrary pull of the attached musculature nonunions can easily occur When such nonunions do occur the region of the transverse process fracture is painful and then it becomes extremely difficult to eliminate the pain because of the depth through the erector spinae muscles which must be traversed in order to remove the offending false joint Because of the occurrence of nonunion resulting in painful backs and occurring with sufficient regularity and with sufficient pain to cause prolonged disability it is felt that such transverse process fractures should not only be placed in a body jacket from the pubis to upper chest but also the patient should remain recumbent until there is roentgenographic evidence of union Union occurs in from four to six weeks

It must be remembered that the crura of the diaphragm the transversalis abdominis the intertransverse multifidus and others of the spinal stabilizers originate from these processes If the patient is up and about the distal fragment is under constant motion due to voluntary and involuntary movement If it becomes necessary in a case of nonunion with painful disability the transverse processes will be found much more easily accessible from a retroperitoneal approach lateral to the erector spinae and starting at the triangle of Petit similar to the approach for lumbar sympathectomy or kidney

Fractures of Articular Processes

Such fracture may occur incidental to crush fracture or fracture dislocation or in dependent of such fractures Where a spine has been injured and the customary antero posterior and lateral films are negative such spines ordinarily clear up with re cumbency adhesive strapping or other ap

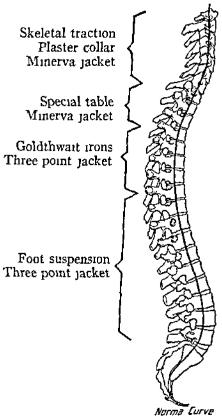


Fig 644 Showing the several different methods of treatment used for simple uncomplicated crush fractures depending upon section of spine involved (Courtesy The Blakiston Co Philadelphia)

propriate treatment for muscle strain. If there is persistence of pain and tenderness at the point of the injury, the spine should be studied further. A repetition of the anteroposterior and lateral projections is indicated, then films taken with the body rotated about 30 to 40°, first on one side and then the other, may exhibit an articular process fracture. The chest and the buttocks must be kept on the same plane when taking such oblique radiograms. However, as is stated elsewhere, the hope of discovering articular process, lamina, or pedicle fractures by roentgenogram is remote indeed. Such fractures are not ordinarily seen unless the case is operated upon and the periosteum is reflected. Such fissure fractures are not important when associated with fractures of the body, for the reason that if the fracture of the body is properly handled the usual fissure fracture in the process will be immobilized if the method of reduction of the body involves a component of horizontal traction.

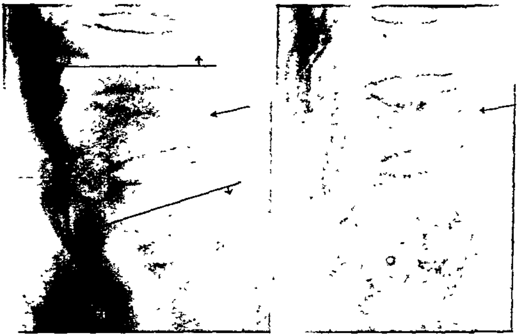


FIG. 645. Case E. G: (*Left*) Typical crush of first lumbar vertebra. Levers illustrate traction and counter-traction exerted by vertebra above and below affected one. (*Right*) Typical reduction by foot suspension.

FRACTURES OF LAMINAE

Direct violence against the spinous process from behind may fracture both laminae and countersink the posterior arch sufficiently to cause direct cord pressure and paralysis — therefore paralysis and evidence of block without fracture of the centrum should indicate immediate open exploration with the possibility of laminectomy.

Unilateral or bilateral fractures of the laminae obviously must be caused by direct violence against the spinous processes, and where such a fracture has occurred with the presence of paralysis, the spinous process with its laminae should immediately be explored because it is obvious that the cord is involved. Provided the patient's status otherwise permits, this operative procedure is imperative. It is the author's opinion that delay is extremely risky. Obviously, a diagnostic spinal tap should be done for the demonstration of blood-tinged fluid and the Queckenstedt test for block.

Hyperextension Fractures of Spine

Fractures of this type are extremely rare because of the unusual conditions required to disrupt the spine with this kind of force Nevertheless extreme types of violence of this kind occasionally do occur The structural iron worker may fall backward for from 10 to 20 feet striking an iron beam crosswise in the lumbar region Thus the leverage of the weight of both ends of the body is directed against the middle and a very serious avulsion fracture of the centrum is the result Thus it may transpire that two 90 pound levers representing the ends plus the velocity induced by the drop combine to exert pressure at the moment of impact against a spinous process This unusual conjuncture of mechanics has occurred resulting in a transverse rupture of the anterior longitudinal ligament The check strap effect of the ligament which safeguards the cord against damage from hyperextension being destroyed hyperextension is not only not effective but positively dangerous Straight line pull using the posterior ligamentous investiture as a check strap and under complete radiographic control with application of a jacket without hyperextension may serve to restore nearly normal conformation of the fractured body

If however this avulsion type fracture

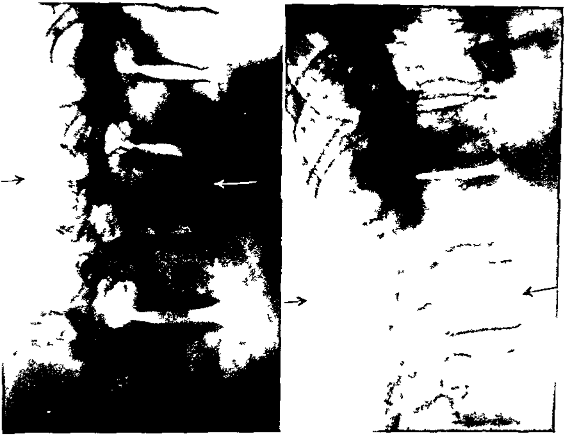


Fig 646 Case A H (*Left*) Very moderate uncomplicated compression of first lumbar Reduction with Goldthwait irons (*Right*) Result three months after reduction with Goldthwait irons Note complete restoration of anterior vertical diameter of the vertebral body

fails to respond to the closed method, operative fusion may be indicated. The diagnosis of such hyperextension fractures may be immediately apparent from the lateral radiogram showing an open space between the fragments of the centrum and increased vertical height of the body. This appearance should give the operator pause and from this point on extreme caution must be brought to bear for fear of dire and immediate results of treatment. When the anterior longitudinal ligament is thus horizontally ruptured, hyperextension may cause immediate paralysis as a direct result of therapy.

Fortunately, the chance of encountering a hyperextension fracture is remote. Automobile head-on collisions involve hyperflexion. Falls from a height unless the victim strikes back foremost some object transverse to the vertical axis of the body, also result in hyperflexion or jackknifing. Cave-ins of earth also cause a hyperflexion squeeze. Obviously, a careful analysis of how the injury occurred will serve as a forewarning of the hyperextension mechanics. Evidence of a contusion over the spinous process posteriorly will also warn the operator of the possibility of hyperextension mechanics.

Unilateral Compression Fractures

Compression fractures occur in which the centrum appears to show a double shadow in the lateral projection. Eleven such cases have been seen in the last 20 years (See Fracture-Dislocations without Paralysis, p 784.) If such a double shadow is seen and in the anteroposterior view a deviation to the side is seen of the vertebra next above the one fractured, one must immediately suspect unilateral dislocation of the articular process. If further examination reveals that the usual space between the spinous processes is altered, it makes the picture complete. Films taken at 30 to 40° show the articular processes more plainly and may be helpful in showing the jumped articular process. It is thought that such cases represent a spiral twist of the torso along with the usual flexion "whiplash." The human spine does not bend directly laterally without the accompaniment of rotation any more than a blade of grass bends with its width without twisting. This analysis of the mechanics involved when compression of one half of a centrum is greater than the other is helpful in determining therapy.

Such cases should be opened in the usual manner as in exposure for a fusion. These dislocations of articular processes are easily reduced during the first week. Later on, however, it will be found impossible to disengage the jumped process and the late cases must be fused if one is to expect a painless back.

Intervertebral Disk

It is impossible to regard a compression fracture of the spine or fracture-dislocation without considering the fate of the intervertebral disk. Plenty of evidence of a roentgenologic kind can be brought forward to show that the nucleus pulposus changes its position permanently as a result of a fracture or other injury to the spine. Narrowing of the intervertebral space is occasionally seen. Obviously, the annulus fibrosus may be ruptured or disarranged as a result of fracture lines running through the epiphyseal plate or the shifting of one vertebra on another, or the momentary increase of intranuclear pressure at the time of the accident. Rupture of nuclear material through fissures of the cartilaginous plate is demonstrated either as a permanent alteration of the form and size of the intervertebral space, or as an area of rarefaction (Schmorl's nodule).

By and large, the intervertebral disk, including its nuclear material, may be disregarded for the reason that the nature of sequelae are such that they do not point toward the intervertebral disk as accountable for residual painful symptoms. Neurologic signs attributable to disk injury have

so far not seemed to feature as a cause of painful disability The reason for this is thought to be that the usual site of sub dural ruptures of the intervertebral disk is at the point of the fourth and fifth lumbar intervertebral spaces The incidence of frac tures at this point is small Higher up in the spine the intraspinal course of the nerve roots is much shorter and therefore not exposed to intraspinal or extradural pressure

General Considerations Governing Pure Dislocations Pure dislocations are limited to the cervical portion of the spinal column The whiplash mechanism in volved in most injuries of the cervical spine produces various degrees and combinations of lesions Whether the accident be due to an automobile head on collision losing one s footing headlong falls or the sudden let ting go of long handled wrenches the mechanism of production is always the same The weight of the head obeying the laws of gravity inertia and momentum tends universally to hyperflex the spine beyond normal range Immediately follow ing such hyperflexion a spontaneous recoil occurs initiated by the strong posterior mus culature The fact also that one of the most universally instinctive reactions is for the individual to recover himself to the point of restoring his vision to the horizontal level augments the recoil impulse This spon taneous recoil factor in the cervical spine serves to conceal in varying degree the de tail and extent of the lesion Were it pos sible to photograph the extreme of deform ity fracture or dislocation at the moment of extreme hyperflexion a much different appraisal of the structures involved would be possible In the cervical region particu larly therefore allowance must be made for some degree of spontaneous reduction when the first films are seen

Reasoning therefore from evidence af forded by the pathological changes seen in complete dislocations the following struc tures in the order of their sequence are those most frequently involved (1) The capsule of the posterior articulations (2) the interspinous ligaments (3) the posterior common ligament and (4) the posterior fibers of the annulus fibrosis

Injuries not involving fracture therefore may be graded as luxations of the posterior facets old creeping or migrating luxations involving neglected fresh luxations of the facets unilateral dislocations involving an element of twist with hyperflexion bilateral dislocations in which the facets are impaled on the pedicles of the subjacent vertebra and finally complete dislocations with sever ance of the cord the only ligamentous structure ordinarily remaining intact being the anterior longitudinal ligament which even in such extreme cases is found to be lifted off but not severed transversely

It is realized that in the case of cervical dislocations unless special study has been given to the subject by the surgeon ma nipulations of any kind are fraught with danger Skeletal traction such as the Crutchfield tongs affords has by now proved itself of surprising efficiency When prop erly executed it can be expected to reduce most of the dislocations and fractures of the cervical spine—in fact it may be said that it has largely superseded the more hazardous manual manipulative methods such as the Walton and Taylor technics herewith described Fig 643 A is an ex ample of the remarkable ease and precision with which severe bilateral dislocations may be reduced Nevertheless the Walton technic for unilateral dislocations as well as the Taylor manipulation for bilateral dislocations are highly effective and must be kept in reserve for cases which do not respond to skeletal traction Very careful analysis in all cases in which patients are submitted to manipulation should be made however before manual reduction is at tempted Skeletal traction nevertheless has largely superseded manipulative methods and seems by far the safest and simplest method

At this point it is important to remember that pulling in a straight line is without danger because of the check-strap effect of the anterior longitudinal ligament. It is also important that once the dislocation is reduced, full hyperextension should be attained, all traction removed, and a hyper extension collar applied It is of the greatest importance that the posterior capsular ligaments which have been disrupted be fully restored in hyperextension so that these ligaments may heal soundly in their shortest length, otherwise healing by scar and a weakened capsule will result. This in turn with the normal use of the head to full range will result in a migration forward over a period of weeks, months, or years, resulting in the chronic luxation type described elsewhere

UNILATERAL CERVICAL DISLOCATIONS

Pure dislocations are limited to the cervical spine. Unilateral dislocations of the cervical spine occur largely in the upper three vertebrae Roentgenography may or may not exhibit conclusive evidence of unilateral dislocation. Usually, however, the lateral roentgenogram shows dislocation of the body somewhat forward, the anteroposterior shows disalignment. Again because of the inability to show the posterior arch adequately, diagnosis by inference from the position of the head is necessary. The head is rotated toward the opposite side from the joint dislocated (Fig. 647). The head is also tilted away from the side of the dislocation.

The Walton technic is unquestionably the superior method for the reduction of unilateral dislocations. The patient is laid supine (Fig. 648). The aim is to use the well side as a fulcrum to rock or derotate the jumped process first upward, then backward, and then into typical hyperextension. In the case of a right dislocation, the right hand of the operator is wrapped around the right mandibular region while the left controls the occiput. With this hold, and the patient lashed to the table, the head is subjected to longitudinal traction, levered to the left, then simultaneously pulled backward and rotated to the right.

The left hand may also be shifted to a position alongside the lateral aspect of the neck on the well side. Strong pressure with this hand helps stabilize the fulcrum, being used as a pinion to lever the dislocated process up and over the one below.

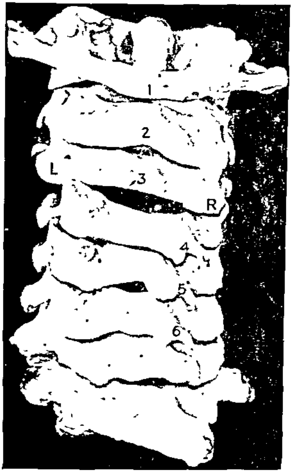


FIG. 647 Unilateral dislocation of cervical spine Note difference in alignment of upper series of three with lower series. Therefore necessary tilting of head to right; wryneck and positive lock of jumped left third process.

Free movement of the head in all directions is the criterion of reduction. Extreme hyperextension as in bilateral dislocations must be maintained for at least four weeks

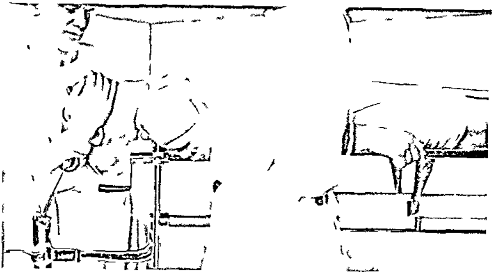


FIG 648 Set up for unilateral cervical dislocation Walton manipulation in process

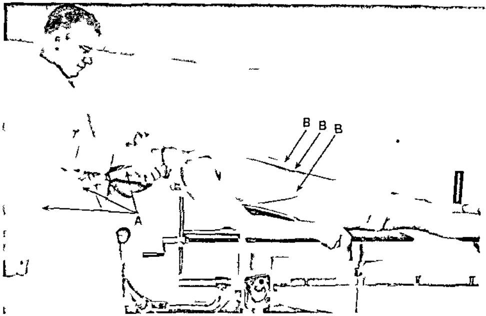


FIG 649 Method of applying straight line pull for bilateral cervical dislocation (A) Halter purchase on occiput and chin Note band extending around buttocks of operator (B) Counter traction bands lash shoulders to perineal post (Operator's foot abuts against stationary object on floor for better purchase)

for a firm ligamentous repair of the joint If complicated by a demonstrable fracture line, three months of adequate splintage is considered necessary to prevent recurrence of painful symptoms. Persistent pain indicates recurrent dislocation or a creeping luxation.

If such a table is not available, an ordinary operating-room table can be put in the Trendelenburg position with the patient lying supine The patient is fixed to the table by passing straps of wide bandage around and above the shoulders and fastening the ends of these slings to a lower point

Fig 650. Case W S (*Left*) Complete bilateral dislocation of fifth cervical forward on sixth (*Right*) After reduction by Taylor method

Bilateral Cervical Dislocations

The set-up for this procedure consists of (1) provision for traction in the exact horizontal (Fig. 649), (2) countertraction provided through keeping the torso fixed, (3) a suitable halter for traction on the chin and occiput, (4) immediate application of a Minerva jacket, and (5) portable x-ray equipment to take a lateral picture. The fracture table, as illustrated in Fig. 636, provides all the requirements for the manipulation and application of plaster as outlined in the set-up.

on the table. As one visualizes the status of the spine with a bilateral dislocation (Fig 650), the jumped articular processes must be drawn upward fairly forcibly and then the head must be dropped backward, still under traction, to a position of hyperextension In order to accomplish this sequence of events, the method of reduction devised by Taylor is employed.

A number of descriptions of the Taylor method are available. The descriptions all agree in principle, but vary somewhat in detail. At this point it is important to re-

member the strength of the anterior longitudinal ligament *

Were it not for this ligament, damage to the cord would undoubtedly ensue as the result of a longitudinal pull Obviously, it would be a decided advantage to pull the head in flexion Pulling in flexion however, puts the maximum traction on the posterior roots of the cord Therefore, it is decidedly the processes below Therefore, pull in the exact longitudinal axis of the body is highly important The use of the canvas sling around the operator's waist or buttocks and attached to the halter affords the operator the best mechanical advantage in handling the head One hand is placed under the jaw, the other under the occiput, and one of the fingers of the occipital hand then placed in

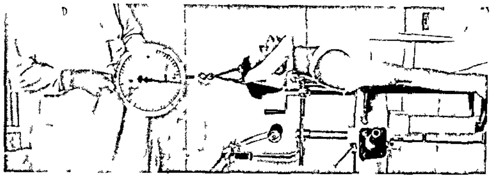


Fig 651 Interposed balance in line of traction to find traction strength of operator in pounds If this is done as a preliminary against end of table and operator pulls to his utmost, the safety factor may be determined in advance (See Tensile Strength Determination, footnote, this page)

unsafe to pull in flexion Pulling longitudinally with extension would, in view of the check strap function of the anterior longitudinal ligament, provide a completely safe method of traction but, unfortunately, the articular processes will not clear each other because the traction will be exerted principally on the anterior longitudinal ligament and the check strap effect of the ligament will preclude the possibility of the jumped processes clearing the summit of contact with the cervical spine and its processes to determine crepitus Ordinarily, distinct crepitus can be felt when the articular processes disengage When this occurs with full traction still maintained on the head, the head is brought into extreme hyperextension A lateral roentgenogram is then taken If reduction has not taken place, another attempt using more traction should be made

It is important at this point to know how much one can pull without doing damage Several individuals were tested at this operative procedure, using a spring balance (Fig 651) It was found that at the extreme of effort the balance registered 80-125 pounds Since the breaking point of the anterior longitudinal ligament is at its weakest 160 pounds, and the average breaking point 337 pounds, it is obvious that pulling to the utmost in the standing position as illustrated will not tear the ligament or otherwise disrupt the cord or nerve roots,

* In a paper published in 1938 results of a series of tests in seven cases were recorded These ligaments were submitted to strains in a testing machine to determine stretch and breaking strength The results demonstrated an average breaking point of 337 pounds with no evidence of stretch Tests to determine the pounds of pull necessary for reduction showed 80 pounds to be sufficient in the heaviest cases The resulting safety factor therefore is in the ratio of 4 to 1 Except therefore in cases of hyperextension injury or fracture dislocations complete assurance may be felt regarding the ability of the anterior longitudinal ligament to withstand the strain of both the initial injury and the reduction

provided the traction is in a straight line involving neither flexion, extension, or lateral deviation.

The position in which the head and neck are placed in relation to the torso is of the utmost importance (Fig. 652). It must be remembered that in order to dislocate the articular processes to the extent that they are completely jumped forward means that the interarticular ligaments are completely torn. In terms of the ultimate convalescence of the patient, it is therefore imperative that the cervical spine be hyperextended to its limit and fixed in this position so that the ruptured ligaments will unite in the short position, otherwise the weight of the head will cause recurrence of the dislocation. A number of newly reduced dislocations of this type have redislocated from a time shortly after the reduction to times later in the convalescence when the weight of the head and flexing of the head has caused gradually increasing luxation, ultimately requiring a fusion operation to fix the spine.

Perhaps the most important point about the application of plaster is to put the head and chin in such a position in relation to the chest that the maximum amount of space exists between these points. Even at the cost of the patient's looking skyward when he becomes ambulatory, such hyperextension is necessary. The application of plaster with the fracture table illustrated in Fig. 637 is quick, easy, and certain. If, however, one is confined to the use of an ordinary operating table and, with an assistant holding the head off the end of the table, a piece of felt is fitted to the skull and the anterior side of the neck and the chest in front to conform to the line of the chin, neck, and chest, and angle of the jaw, neck, and shoulders, the felt is modeled to all the irregularities in this area The plaster then covers the felt.

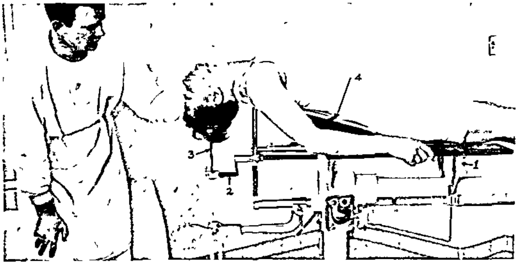


FIG. 652. After reduction of cervical dislocation. Ready for application of plaster cuirass. (1) Brackets to hold table leaves; (2) crank to tense hammock, (3) head rest permits extreme extension; (4) lower level of jacket.

After this section of the cast has been fitted, the patient may be shifted so that his shoulders hang off the end of the table, then the rest of the chest and circular portion around the head may be applied, thus yielding a half jacket, but a half jacket in which hyperextension of the neck is guaranteed. The patient may then be rolled onto a stretcher and a posterior section from the occiput over the neck and shoulders fashioned. These anterior and posterior shells are then held together with a buckled strap.

Either half may be removed for bathing while the other half remains to hold the reduction

Convalescence Ordinarily a month is spent in such a jacket either ambulatory or recumbent depending upon the general status of the patient The next day after the patient becomes ambulatory lateral radiograms should be taken to see that the reduction is being fully maintained After a month provided there is no fracture a plaster cardboard or Schantz collar will maintain hyperextension for the next two to four weeks Ligamentous structures do not require the period of fixation necessary for fractures in which structural callus is necessary Physiotherapy may or may not be necessary Normal use is usually sufficient to limber up the injured area (See Unusual Fractures of Cervical Region Case W P Fig 664 p 794)

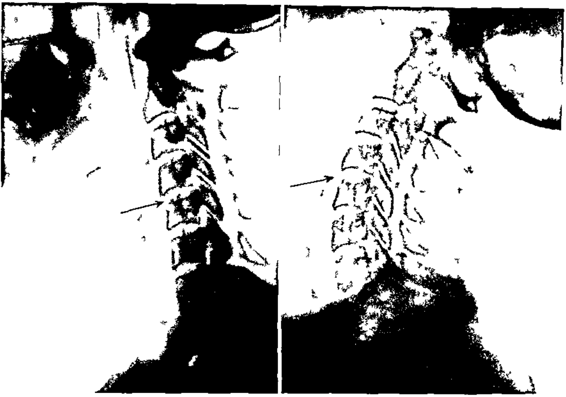


FIG 653 Case M M (*Left*) Typical partial dislocation of cervical spine Arrow points to slight forward displacement of body of fourth Note elimination of normal cervical forward curvature (*Right*) Schantz collar in place Normal symmetrical cervical curve exaggerated (hyperextended) Discrepancy at fourth intervertebral space has been eliminated

CERVICAL LUXATIONS

Since recognizing the importance of straightness of the cervical spine as exhibited by the first lateral projection a constantly increasing number of these luxation lesions have been identified The first case in the author s hands to come under this classification occurred in 1936 (Fig 653) Since then a technic has been developed to demonstrate conclusively the damage to the capsule of the posterior articulation When patients report to the physician with pain and spasm in the neck with variable pain radiation and the first stand

ard lateral film shows straightness of the cervical spine, this elimination of the normal anterior curvature is interpreted as being abnormal. This appearance indicates the necessity of further study

Two positions are posed. Position 1, the patient relaxed in the sitting position the gaze focused on a point level with the eye, the patient holding sandbags in the hands in order to depress the shoulders; and then position 2, the chin-chest position, i e., the head pushed forward to approximate the chin as near the chest as possible in order to obtain maximum range of forward neck flexion.

Figs. 653 A and 653 B show what may be expected normally. Fig. 653 C shows the difference in the interarticular space in the two positions Fig 653 D shows how a dislocation is completely eclipsed by the extensor recoil and can be exhibited only in extreme flexion. Fig. 654 shows an old lesion involving the fourth nerve root. Fig. 663 is a case involving the seventh root with severe causalgia radiating to the radial side of the hand and paralysis of the long thoracic. Fig. 654 A shows a case with bilateral shoulder radiation.

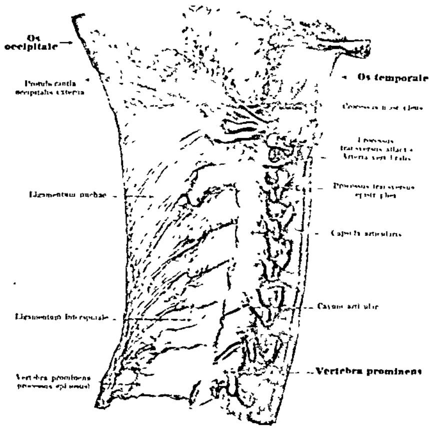


FIG 653 A Skull and cervical spine with ligaments, from the right. (Joint slits partially opened.) (Courtesy, Spalteholz, W Hand-Atlas of Human Anatomy, 7th ed, Philadelphia, J. B Lippincott Co.)

An analysis of 73 cases of the obscure type heretofore diagnosed as indefinite sprain, etc., shows the following distribution of root pain: (1) The occipital, (2) the third and fourth cervical, (3) the fifth, (4) the sixth, (5) the seventh, (6) those in which precordial pain of the anginoid type was a prominent feature, and (7) those in

which the long thoracic nerve was involved, of which there were two

A specific diagnosis therefore rests on the correlation of specific x ray findings at a definite level and a clearly defined dermatome radiation This brings one inevitably to a diagnosis of injury, recent or old, at a definite level

the posterior capsule Involvement of the posterior component inevitably means involvement of the anterior joints If the posterior joints alone are involved in luxation pain radiation is usually present and follows the pattern of the root distribution at the level involved If there is an intervertebral disk rupture, the pain radiation

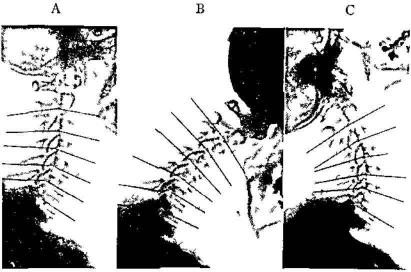


FIG 653 B Functional anatomy For this purpose arbitrary points were selected on each vertebra and lines extended to visualize the movement A is in relaxation with eyes horizontal position 1 Note that posterior lines are nearly parallel, evenly spaced, and horizontal (in balance) B shows 'chin chest' position and degree of deviation of lines is variable Sixth and seventh remain nearly horizontal Greatest range is seen between fourth and sixth Note in C convergence of posterior lines is maximal between third and sixth In terms of "whip lash' mechanism it will be seen that sixth and seventh form *stock* of whip and the upper vertebrae the *lash* Movement indicated by anterior lines is best explained by movement involved in shift of nucleus pulposus approximation of the anterior edges of vertebrae in B being consistent with convergence of lines just as divergence of lines in C is accompanied by an approximation of posterior edges of body

Much is being learned at present concerning intervertebral disk lesions in the cervical spine As a resultant of the "rocker" movement characteristic of the cervical vertebrae in the anteroposterior direction, it is clear that the "whiplash' mechanism of production must produce rupture of the posterior common ligament and protrusion of the nucleus pulposus as well as tearing of

is over the same area, is ordinarily considerably more intense, and is frequently accompanied by a diminution of reflexes such as the biceps or triceps and sometimes by atrophy of the thenar eminence

Combining the different kinds of involvement exhibited by special roentgenography with neurologic findings, we therefore arrive at four kinds of lesions (1) Luxation

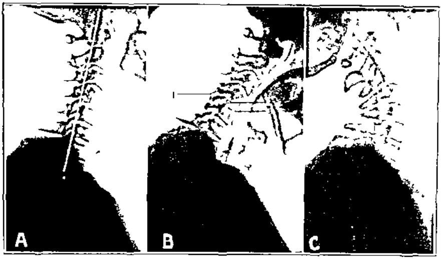


FIG. 653 C. Localization of lesion Four years prior to these x-rays patient sustained an electrical shock. During the effort to withdraw his hand from contact with wires, a severe "throw" of the head occurred. Patient experiences occasional pain and stiffness in the neck with shoulder radiation which he relieves posturally. Note the straightness of the spine in A, also forward tilting of the body as measured by the body of the fourth. B1 shows the excursion of the posterior edge of the superjacent articular process from the subjacent one. B2 shows the separation of the posterior edges of the body and the shifting of the nucleus to account for this spread B3 shows the approximation of the anterior edges and C shows how hyperextension restores all normal relationships (Courtesy, Jour. Amer Med Asso.)

FIG. 653 D. Luxation cervical vertebrae 2, 3. Child of seven years. Automobile accident. Multiple fractures. Could not sit up, fell over each time from dizziness. Limited neck movements. Note the dislocation well forward at "chin-chest" position. Complete recovery in plaster collar. (*Left*) Standard lateral view. (*Center*) Voluntary flexion ("chin-chest"). (*Right*) Extension in Schantz collar.

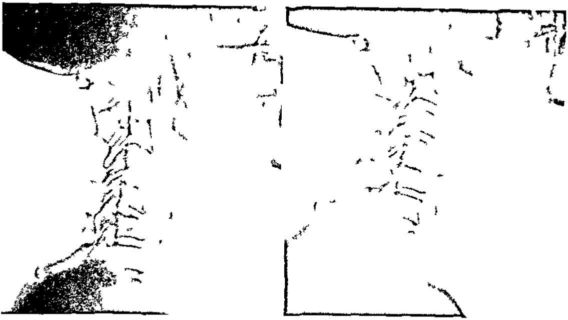


FIG 654 Case J K (*Left*) Longstanding partial dislocation of third cervical forward on fourth Note elimination of normal cervical forward curve

(*Right*) Postoperative fusion Third fourth and fifth vertebrae are fused to eliminate painful disability

A B C

FIG 654 A Luxation cervical vertebrae 4 5 Patient stumbled on slippery floor First seen ten days after Bilateral shoulder girdle pain

A (*Left*) Normal lateral view

B (*Center*) Chin chest

C (*Right*) Hyperextension in plaster collar

Immediate disappearance of symptom Collar removed six weeks later No recurrence Note discrepancies at C 4 5 level posterior borders anterior borders and interspinous space in B

of the posterior facets, (2) narrowing of the intervertebral space, (3) lesions encroaching on the intervertebral foramen, or (4) a combination of any two or all.

Treatment. If the luxation is of very recent occurrence it is important to apply a collar in hyperextension and to maintain this position for about three to four weeks. If the condition is old and fails to respond to postural training it may be necessary to fuse the two involved vertebrae as in Fig. 654. In the case of a disk lesion where the disk is seen to be definitely narrowed or there is evidence of a traumatic arthritis of the intervertebral joints, "hanging" stretching together with the wearing of a protective collar and physiotherapy may relieve the symptoms. The matter of operative treatment for old lesions in which there is intractable causalgia depends upon conclusive evidence of intervertebral disk protrusion sufficient to cause a pressure neuritis of the nerve root and on the question of fusion. Further investigation and end-result studies are necessary to differentiate fully the luxation type from the disk protrusion type of cervical injury and for the proper remedy for the combined lesion. It seems logical, however, from the nature of the "whiplash" production of the injury and the fact that injuries involving the posterior joints inevitably involve the anterior joints since the vertebrae move as a whole, that the combination of an intervertebral disk operation and spinal fusion at the same level must be considered in such cases. Much progress is at present being made in regard to disk lesions in the cervical spine. Not until end-result studies in sufficient numbers have been made will it be possible to outline definitely a routine of therapy for such lesions.

From the point of view of the prevention of gradually migrating luxations and gradually increasing traumatic arthritis of the intervertebral joint it is clear that if such lesions are definitely recognized and specifically diagnosed by careful roentgenography that much can be done to prevent the more severe disk and posterior joint lesions. If such cases are immediately hyperextended following accident, the necessity for later operation in most cases will probably not arise. (See Unusual Fractures of Cervical Region, Case J. J., Fig. 662, p. 794; and Case A. T., Fig. 663, p. 794.)

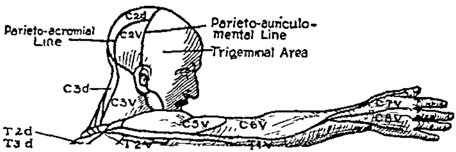


FIG. 654 B. Outline of areas commonly involved in cervical spine lesion. (Courtesy, Tilney and Riley, The Form and Function of the Central Nervous System, New York, Paul B. Hoeber, Inc.)

POSTERIOR DISLOCATION OF FIFTH LUMBAR VERTEBRA

A comparatively rare injury to the spine is that of posterior dislocation of the fifth lumbar at the lumbosacral joint (Fig. 655). This injury apparently occurs as the result of direct trauma to the back causing hyperextension. Unusual precautions must be taken in the roentgenography at this point and for this condition.

A diagnosis should not be made on the

basis of one lateral film The condition is usually discovered as a result of searching for a diagnosis in a disabled spine in which the symptoms are referred to this point and otherwise unexplained A confirmatory film should always be taken and the diagnostician should see that the film is taken exactly perpendicular to the sagittal plane in other words an exact lateral and centered directly over the lumbosacral joint If the second film shows that both the posterior and anterior borders of the vertebra are disaligned with the sacrum below and disalignment demonstrates the fifth lumbar to be posterior and of course if no other lesion can be demonstrated then one has a right to assume that the posterior dislocation is causing the painful disability The author has seen no cases immediately post accident but has seen several cases in which trauma of a severe kind featured to begin with The dislocation definitely was demonstrable and a fusion in each case resulted in a symptomless spine The fusion should include *from the fourth lumbar to the sacrum*

FIG 655 Case E L Posterior dislocation of lumbar spine on sacrum Bilateral sciatic pain radiation Fusion from fourth lumbar to sacrum in deformed position completely relieved painful disability

These cases are quite universally accompanied by pain over the back and posterior thigh—the same distribution as the pain complained of in spondylolisthesis

FRACTURE DISLOCATIONS WITHOUT PARALYSIS

Until now we have dealt with entities in which a *well* charted course is profitable and good results are the rule From now on however the course of therapy is infinitely less certain does not lend itself to definite charting and is infinitely more dangerous Throughout this outline the more dangerous pitfalls as they have occurred in practice will be pointed out

Diagnosis by inference of posterior arch lesions must be resorted to since the radiogram cannot be depended upon to show even gross lesions involving the pedicles the articular processes and the laminae One is frequently tricked into the illusion of a completely normal appearing posterior arch fissure fractures for instance without gross displacement are impossible to exhibit by ordinary roentgenography Fig 656 depicts an autopsy spine in which a number of fractures of the pedicle and articular processes were made with a Gigli saw A study of the four views of this spine shows but two fractures It is noted in this connection that the Gigli saw creates a considerably greater defect than a simple fissure fracture in a bone

While it is generally known that the radiogram seldom shows all the lines of the fracture in a long bone in the case of the posterior arch the concealment of cracks and dislocations is much more effective than it is in the long bone because of the very dense bone forming the accessory processes

and the number of such processes, particularly in the lateral plane.

A glance at the spine shows how impossible it is to hope to reveal the fracture or dislocation by photography because of the number of processes to be penetrated by the rays. In the lateral radiogram, for instance, it is necessary to penetrate both lateral processes, four articular processes and also two pedicles. If a line of fracture shows, it is by the merest chance, and it is necessary either for the defect to be large or the dislocation gross.

Radiograms taken at 30 to 40° are more likely to exhibit fracture lines in the articular processes than the lateral roentgenogram. The majority of such oblique radiograms, however, cannot be expected to show much more than irregularity of the posterior articulations. The lack of visual evidence of fault in the posterior arch will continue to deceive most observers and will undoubtedly continue to create a false sense of security because of negative findings. No doubt greatly increased caution is exercised by most operators in their approach to fracture-dislocations with paralysis. It is the damaged cord in this case which warns the operator.

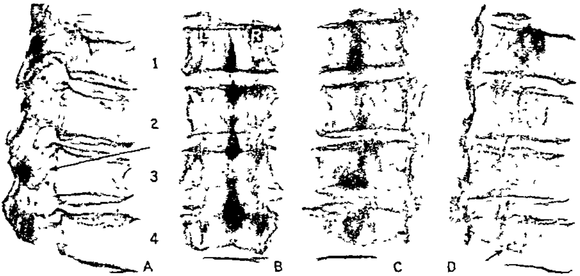


FIG. 656 Radiographic concealment. (A) Lateral, (B) anteroposterior, (C) right, and (D) left oblique projections of autopsy spine Fractures were made at various points in posterior arch with a Gigli saw. A sample of defect created by saw is indicated by arrows. The other fractures contain the same amount of defect but defects are concealed by overlying dense bone. The fractures actually present in the 4 vertebrae were as follows:

Left side of vertebra	*Right side of vertebra*
(1) Intact.	(1) Articular process fracture.
(2) Tip of articular process fracture.	(2) Pedicle fracture.
(3) Intact.	(3) Pedicle fracture.
(4) Articular process fracture.	(4) Articular process fracture.

Fracture-dislocations of fully as great magnitude but without paralysis occur regularly. In the paralyzed case, one must assume risks which would not be warranted in simple crush fractures. The greatest danger, however, is that of the operator doing real damage to a fracture-dislocation without paralysis. Means of identifying the dangerous types are as follows:

The radiograms must be observed from the point of view of damage to the posterior arch. With this approach in mind, certain points become immediately obvious. The

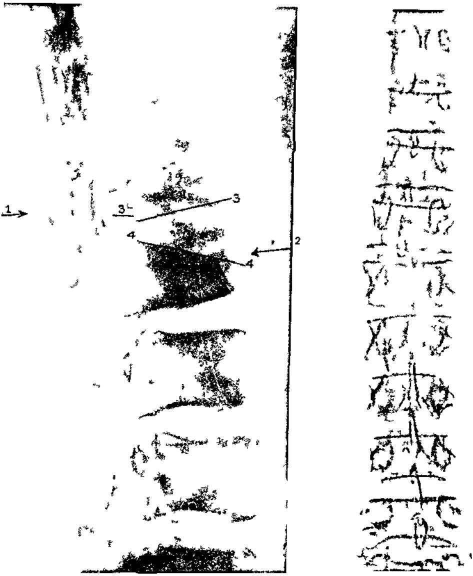


Fig 657 Case B G (*Left*) Fracture dislocation of first lumbar (1) Indicates gross enlargement of intervertebral foramen Articular process of twelfth dorsal has dislocated upward and is impaled upon superior articular process of first lumbar (2) Indicates compression unreduced after attempt at hyper extension Impinging articular processes do not permit normal fulcrum of posterior joint to operate therefore disimpaction is impossible until processes have been disengaged (3) Indicates level of one side of crushed centrum (4) Indicates lower level of opposite side

(*Right*) Anteroposterior projection observations Note (1) Lateral angulation (2) Wide space between spinous processes (3) Different alignment of series of spinous processes above and below dislocation (4) Unequal compression of two sides of body Compare with left part of illustration

correlation of a number of these points will frequently decide which case is to be manipulated and which to be operated. By observing all radiograms of spinal injuries in this light, the operator will safeguard himself against disasters due to manipulation.

Fig. 657 depicts a case of this kind clearly. This patient presented no neurologic signs whatever. Four points were noted in the anteroposterior view:

1. The lateral angulation with its apex at the twelfth interspace.

2. The wide interval between the spinous processes of the twelfth dorsal and the first lumbar.

3. The definite rotation of the entire upper section as indicated by the spinous-process alignment of the upper section with that of the alignment of the lower section.

4. The unequal compression of the two halves of the body. This case was one of a slender boy where radiography is at its best and shows clearly the articular processes.

The lateral view brings out additional points:

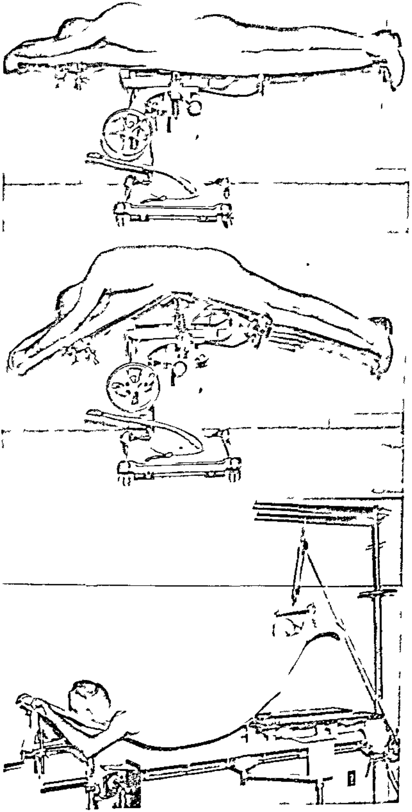
1. Gross enlargement of the intervertebral foramen.

2. The appearance of one articular process being impaled upon the one below, also the two different levels appearing in the centrum indicated at points 3 and 4.

Wherever this double shadow of the vertebra appears, the dislocation of one articular process must be expected. Fig. 658 is an exact replica of the case just cited. When analyzed, this anatomic specimen shows the right twelfth process jumped and locked in front of the right upper process of the first lumbar. It also shows the almost complete dislocation of the left process.

An analysis of this specimen shows why the angulation, rotation, and disalignment of the spinous processes with large interspinous space all combine to make certain the diagnosis of a jumped articular process, and demonstrates conclusively the impossibility of safely reducing such a case by

FIG. 658. Demonstration of factors entering into diagnosis of fracture-dislocation of lumbar region. (1) Lateral tilting of twelfth; (2) different alignments of upper and lower series of spinous processes; (3) lateral angulation of two spinal segments; (4) rotation localized to point of dislocation as indicated by lateral offset of twelfth; (5) wide vertical separation of twelfth and first spinous processes.



manipulation. It is considered definitely hazardous to attempt any manipulation at all. The sequence of treatment believed to be best for this type of case is as follows:

The patient is mounted on an operating table which breaks in the middle, shown in Fig. 659. The posterior arch is exposed by the subperiosteal method as in fusions. The laminae and articular processes are exposed in detail. The table is then broken so as to induce the necessary flexion to disengage the jumped process. When using the special table, a cross sling is placed transversely underneath the fractured area and flexion is induced by simply elevating the suspension apparatus until the process has room for clearance. A bone forceps then grasps the spinous process of the dislocated vertebra or a blunt elevator is used to pry the process over. Combining movements of posterior pull with rotation, the table is then straightened away, the sling lowered, and the dislocation thus rather easily reduced.

With the operative wound still open, the patient is hyperextended by foot suspension and a lateral roentgenogram is taken in order to see that the centrum is fully restored to its vertical diameter. Obviously, no fusion is necessary in such cases. If, however, the posterior arch is otherwise damaged, fusion may be indicated.

Fig. 660 illustrates another such case. This case was not opened It shows most of the features necessary to a diagnosis of a dislocation of the posterior articular process. The radiogram six months after fracture shows that the patient was saved from further gradual dislocation forward by a bony bridge existing between the two vertebrae in front. There is practically no evidence of continuity of structure of the posterior arch.

According to the history, a number of attempts were made to manipulate this latter case to undo the deformity of the centrum. Obviously, the centrum could not be opened to its complete height because of the block afforded by the jumped process posteriorly. It must be noted again that neither of these cases showed any neurologic signs. Obviously, attempts at manipulation of such cases is extremely hazardous.

FRACTURE-DISLOCATIONS WITH PARTIAL OR COMPLETE CORD INVOLVEMENT

No exact line of demarcation can be drawn between the simple crush of a centrum without cord involvement and the other extreme of complete shearing of the spine and cord, for which nothing can be done. No rule of thumb can be conjured to differentiate with certainty the case which requires laminectomy from the one that requires hyperextension only and the one that requires both.

A preponderance of evidence can usually be adduced for conservative or radical procedure. Experience in many hands proves, however, that laminectomy occupies a distinctly secondary place in the treatment of fracture-dislocations with paralysis. Each case must be carefully analyzed and assessed upon its own merits A careful evaluation of the many factors involved will usually bring one to a definite conclusion as to therapy.

The usual factors to be considered as im-

FIG. 659. (*Top*) Depicts usual table position for operative fusion.
(*Center*) After exposure, table is broken and lumbar spine flexed by elevating kidney rest and breaking table sufficiently to clear the jumped process. Table is then restored to horizontal and obstructing process is either engaged normally with its partner or removed, or, if rotation cannot be bridged, a fusion may be indicated immediately. If procedure is successful and processes engage readily, then foot suspension is immediately indicated to "open up" the compressed centrum and a jacket is applied as in bottom illustration. Lacking proper equipment for foot suspension, operator must provide an overhead suspension hook, block and tackle, spreader, and hammock. This equipment may be improvised in many ways. The hook should be tested to withstand 100 lbs. weight.

portant in arriving at logical therapy are as follows

1 The usually apparent paralysis accompanied by a careful neurologic analysis to determine whether the paralysis be complete at a definite level or partial

2 The results of the Queckenstedt test ability of transitory edema contusion compression or transection Frequently it is quite impossible to decide as between these entities

5 The element of time which is urgent in relation to progressive paralysis hematomyelia compression or laceration

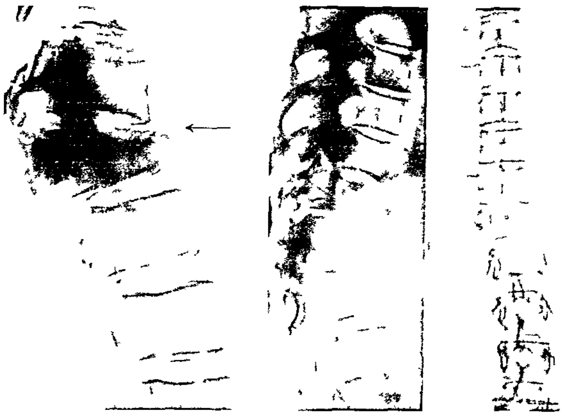


FIG 660 Case M P (*Left*) Fracture dislocation without paralysis Note (1) Gross enlargement of intervertebral foramen and (2) articular process caught on apex of process below therefore closed manipulation futile

(*Center*) Lateral view after six months Complete interruption of continuity in posterior arch Note (1) Inability to exhibit detail of articular process (2) apparent bony bridge at anterior portion and (3) failure of reputedly strenuous attempts at hyper extension to decompress centrum or correct angulation

(*Right*) Six months after fracture Note (1) Lateral dislocation and (2) unequal compression as between the two sides

3 The amount and nature of deformity in relation to the spinal canal and the question of its reducibility or irreducibility by manipulation or laminectomy or both

4 An attempt to arrive at a conclusion based on neurologic findings and the results of the Queckenstedt test as to the probability of transitory edema contusion compression or transection

6 The status of the patient whether operable or not It must be remembered in this connection that in paralyzed cases a laminectomy can be done without general anesthesia in most of the cases Local infiltration anesthesia is quite sufficient

The element of recoil at the time of the

accident tends to spontaneously reduce the fracture-dislocation. By the time the patient arrives at the hospital and the first radiogram is taken, the cord may have been severed by a complete dislocation and a complete spontaneous reduction may have occurred. It is safer, therefore, to assume that in all cases the degree of displacement was greater at the time of the accident than the first picture would indicate. The record shows that, in completely paralyzed cases, laminectomies are almost completely futile. The region involved has a decided bearing on the likelihood of recovery from a completely paralyzed status. Above the level of the second lumbar vertebra there is no ability of the cord substance to regenerate; below this level the cauda equina possesses the power of regeneration.

In doubtful cases, therefore, laminectomy is more applicable in the lumbar region. It must also be remembered that hyperextension accomplishes an increase in all the diameters of the spinal canal, and that if the Queckenstedt test shows a complete block before hyperextension and a release of the block after hyperextension, laminectomy for the time at least may be postponed. Only in those rare cases where the radiogram exhibits impingement of a fragment of bone in the spinal canal is laminectomy imperative at the earliest moment. It is important to remember that neurologic examinations should be made repeatedly. In cases where such examinations show increasing paralysis, obviously laminectomy with the possibility of incision of the commissure is indicated at the earliest moment. In the majority of cases when the deep reflexes are obliterated, sensation lost, muscle action gone, and Babinski absent, irreparable damage has been done.

However, occasionally a case occurs where, after hyperextension has been instituted at a very early stage and where the neurologic signs point to a complete lesion even with the presence of priapism and involuntary stools, an almost complete recovery has taken place. It is this paradoxical clinical experience which demonstrates that conclusions regarding the status of the cord are quite impossible from a neurologic examination. Such recoveries can be explained only on the basis of contusion and localized edema of the cord.

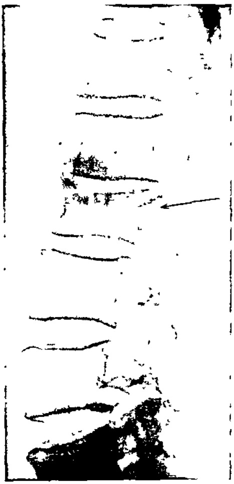


FIG. 661. Case P. M. S. Typical protrusion of posterior bony fragment Sufficient to cause partial permanent destruction of cauda equina Decompression laminectomy six months after initial treatment resulted in some improvement.

The fact, therefore, that occasional cases which apparently have been completely paralyzed at the beginning have recovered after proper hyperextension—the fact also that most laminectomies in completely

paralyzed cases have revealed pulpified cord substance—the admitted inability to make a definite diagnosis as between cord destruction and cord contusion—the fact that regardless of laminectomy the spinal column must be returned to its normal contour in order to attain complete recovery—the quickness with which hyperextension can be applied immediately the patient arrives in the hospital whether the lesion be cervical or in other parts of the spine as compared to the delay necessary to prepare the patient for operation and the delay necessary to a complete diagnosis—the fact that the posterior upper angle of the involved centrum is the usual compressing medium (Fig 661) together with the fact that hyperextension is known to open the canal to its greatest diameter at the point of fracture all of these factors point to the importance of hyperextension as a decompressing medium probably as efficient as if not more efficient than laminectomy The fact that hyperextension at the earliest possible moment after the patient arrives at the hospital relieves pain reduces deformity and opens the spinal canal to its largest diameter whether it be skeletal traction for the cervical fracture dislocation or foot suspension for a thoracolumbar fracture dislocation testifies to the helpfulness afforded by the use of preliminary hyperextension

If the patient is permitted to assume any position he pleases awaiting a decision as to when laminectomy is to be performed every moment wasted in this manner increases the pain shock and hazard whether or not a laminectomy must eventually be performed It would appear therefore that as a general rule paralyzed cases should immediately be put in a position of hyperextension wherever they may occur in the spine and in the light of overwhelming statistical data against laminectomy laminectomy should be reserved for very carefully chosen cases

From the author s point of view excluding the exceptional case of fracture of the laminae with compression of the cord hyperextension by the gradual method or by actual foot suspension (where the element of dislocation is the lesser feature) and skeletal traction in hyperextension for the cervical region are immediately brought to bear the moment the paralysis is observed The Queckenstedt test is then executed and provided sufficient hyperextension is exhibited in the radiogram and a block is demonstrated by the spinal fluid pressure then laminectomy is considered but if the anatomic repositioning is nearly perfect and the spinal canal appears to be open to its greatest diameter again laminectomy is postponed and in the great majority of completely paralyzed cases laminectomy is never performed because of the known futility of the procedure In most fatal cases permission for autopsy has been granted and irreparable lesions demonstrated

The area containing the cauda equina is throughout considered more eligible for laminectomy than that part of the spine containing the spinal cord proper Again it is the author s impression that while very few cases will recover from complete paralysis whether laminectomized or hyperextended the evidence of completely paralyzed cases having recovered almost complete function with hyperextension inclines the author to the belief that as many or more will recover with hyperextension alone provided laminectomy is always kept in mind for those cases where there is increasing paralysis or cases which prove irreducible by hyperextension In a number of cases it will be found that the preliminary hyperextension followed by the making of shells is necessary before laminectomy is done

The usual routine followed by the author in completely paralyzed cases is as follows

1 Place in the optimum position to gain hyperextension immediately upon entrance to the hospital

2. Make a neurologic examination, preferably by a neurologist or a neurosurgeon.

3. Apply the Queckenstedt test at the earliest opportunity.

4. If there is no pressure response, apply hyperextension unless radiograms contraindicate.

5. Again apply the Queckenstedt test. If return of pressure is demonstrated, decompression has taken place.

6. Repeat the neurologic examination at intervals.

7. Meanwhile, apply proper urologic care to insure bladder drainage.

8. If the fracture is irreducible by manipulation, exploration of the posterior arch may be indicated to reduce a jumped process.

9. The period of a week will usually determine whether recovery will or will not take place unless the level involves the cauda equina in the lumbar region, in which case return may take place at a later period.

Hopelessly Paralyzed Fracture-Dislocations

If, after the first few days, it is found that no recovery is taking place and the patient shows signs of total paralysis with a definite level and there is incontinence of urine and feces, the principal problem is that of nursing care. Urologic consultation is necessary to decide the manner of drainage—whether by suprapubic cystostomy or by allowing distention of the bladder as the fastest method of producing an automatic bladder. It will be found that, in order to prevent development of bedsores, an anterior and posterior shell should be made, being carefully modeled to impress the soft parts and avoid the bony prominences. Such shells should extend from the knee to the shoulders, with suitable apertures cut out anteriorly and posteriorly. The shells are strapped together with trunk straps and the whole ensemble is mounted on a Bradford frame. The patient is turned two or three times a day, one shell being removed at a time in order to allow proper skin care. If the patient lives through the urinary complication, he may go on eventually to some sort of walking with crutches or lead a life in a wheelchair.

UNUSUAL FRACTURES OF CERVICAL REGION

The following three cases are cited as examples of the care that must be exercised in interpreting so-called strains of the cervical region. Both cases show the necessity of splinting from the beginning. Both serve to reiterate the point of the unknown magnitude of the injury at the moment the injury is sustained in relation to the very few signs shown at the time the patient is first seen.

A dislocation or sprain-fracture with the usual ripping of the ligaments of considerable magnitude frequently takes place. The immediate spontaneous recoil tends to conceal the extent of damage occurring to nerve roots, accessory processes, and ligamentous structures. Subsequent normal use of the head in flexion, extension, lateral bending, and rotation obviously must increase the degree of deformity so that what appears to be a trivial lesion to begin with becomes a major disability later.

Case J. J., a young woman aged 34, showed a typical seventh cervical nerve syndrome. The lesion can be seen plainly in Fig. 662. She was first seen in June, 1941. Her history then was that in April, 1940, while working in a library, she slipped on a freshly waxed floor. She threw out her hand to protect herself in falling and caught hold of a bookcase. She felt sudden pain at the base of the neck on the right side. She consulted a local doctor but no treatment seemed indicated. She felt very little pain for a week, then, upon awakening one morning, she felt sudden severe pain in the right angle of the neck. She was then hospitalized for ten days. She suffered severe pain for a few weeks, but then the condition became

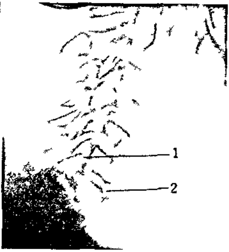


Fig 662 Case J J (*Left* and *Center*) Roentgenograms one year following injury Note (1) size of articular process

Fig 663 Case A T (*Right*) Long thoracic paralysis Note (1) evidence of injury of articular process and (2) evidence of old fracture Also note narrowing of inter vertebral space

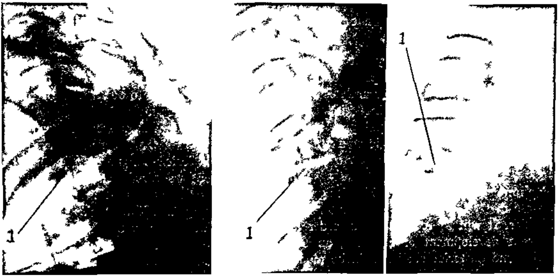


Fig 664 Case W T Irreducible cervical fracture dislocation Note (1) position before (*left*) during (*center*) and after (*right*) attempt at reduction Also note vertical line of fracture dividing centrum of sixth into two halves and marked depression of inferior surface of sixth

stationary. The condition had remained unchanged since the first few weeks after injury. She complained of pain running down the right arm and a feeling of numbness in the thumb and index finger. Use of the right arm brought on pain.

Following is the neurologic examination by K. G. Mackenzie, of the Toronto General Hospital.

No atrophy of the arm, forearm, or intrinsic muscles. Reflexes and strength of the biceps and triceps, normal. Strength of the intrinsic muscles, normal. There is some definite paresthesia and a "pins and needles" feeling over the radial side of the hand.

At times the hand seems to feel useless and she drops things. She has very little pain It is my opinion that this calcification is part of an extruded disk which has produced some trauma and neuritis of the seventh root.

Case A. T., paralysis of the long thoracic (Fig. 663). The patient was referred for an impartial examination and opinion for the question of disability, the history being as follows. A 3 by 12 timber fell from a wooden horse. The patient at the time was carrying the horse supporting the timber. Upon falling, the timber struck the patient's left shoulder a glancing blow, and then fell to the ground. The case was argued back and forth in industrial courts and there was wide divergence of expert opinion. The patient's complaint throughout a period of four years was of pain radiating down the left arm diffusely to the fingers, pain in the left angle of the neck, that he carried his head in the position of a left torticollis, and that he had difficulty doing hard work—in fact, anything that opened the angle of the neck apparently caused severe pain radiating down the left arm. The outstanding sign, however, was that, when the patient was asked to push forward against resistance with his left arm, the left scapula protruded prominently posteriorly.

Paralysis of most of the fibers of the serratus magnus must be assumed. While the roentgenologic evidence is rather slight, nevertheless its location is completely consistent with involvement of the long thoracic and consistent with his causalgia.

Case W. P. (Fig 664), bilateral fracture-dislocation of the sixth cervical vertebra. This case is cited as one in which manipulative reduction proved impossible. To begin with, the Crutchfield tongs were applied and traction up to 35 pounds was brought to bear without effect. A manipulation was then done in the manner illustrated in Fig. 649. Several attempts were made with this type of straight-line traction, even inducing a little flexion, both the author and an associate putting their fullest power of manual traction to test. X-rays taken at the time showed that, while improvement in the position took place, it appeared impossible to dislodge the inferior articular processes of the sixth from the processes of the seventh. The body of the vertebra seemed to move somewhat backward but not sufficiently to obtain reduction The procedure was again tried the following day under full anesthesia, but even under these conditions it was impossible to dislodge the articular processes.

In attempting to explain the failure of the correct application of the Taylor method in this case, it would appear that the vertical line of fracture through the body of the sixth can be held accountable. It should be remembered that the cervical spine is normally curved forward, and that when strong traction is applied in a straight line this normal forward curvature disappears. A pure dislocation without fracture of the centrum during such straight-line traction induces leverage exerted by the anterior edge of the vertebra below against the lower surface of the dislocated one. This leverage thus aids the operator to disengage the jumped processes.

Hyperextension then reduces the processes to their normal position. When the exterior half of a dislocated vertebra is involved, the impingement of the anterior upper corner of (in this case) the seventh

completely collapses the body of the vertebra at the point of impingement and no leverage can be expected as occurs in an intact body It is therefore assumed that in the process of reducing a bilateral dislocation by the Taylor method the two components of reduction are horizontal traction and leverage, as described

The only time this patient experienced *neurologic symptoms was during the strong* traction, when he said he felt "tingling' running down the both upper extremities He was therefore fused in the deformed position and it is expected that he will have a full recovery without painful symptoms in spite of the deformity

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27

Treatment of Fractures of Pelvis, Sacrum, and Coccyx

PAUL B STEELE, M D

The primary consideration in the treatment of all fractures of the pelvis is shock The degree of shock should be determined immediately and treatment given accordingly [See Chapter 22 —Ed] In very severe accident cases the fracture of the pelvis is frequently a secondary factor necessitating the treatment of the complication as the major lesion

Grave complications which may be encountered are hemorrhage paralytic ileus rupture of the bladder and urethra genitourinary infections and phlebitis

The presence of a large amount of blood tinged urine on catheterization does not mean that the bladder has not been ruptured as there may be a small hole near the base which will leak sparingly into the peritoneum causing peritonitis Thus the importance of suspecting some rupture where blood is found should always be borne in mind Where rupture of the bladder is suspected an injection of some opaque fluid into the bladder is indicated and anteroposterior and lateral x rays should be taken With the assistance of x rays and a physical examination the surgeon can determine the site and degree of injury to the soft tissues and bones of the pelvis

The treatment of the complications other than those involving bones and joints are found elsewhere in this book under their proper heading [See Chapter 22 —Ed] It is not the object of this chapter to consider the diagnosis but to formulate the present accepted methods of treatment

FRACTURES OF WING OF ILIUM

The patient is placed in bed in a recumbent position Bimanual manipulation into correct position is usually accomplished by simple compression of the fragment Adhesive strapping is then applied under pressure and in such a manner that it holds the fractured portion in position using two or three strips of three inch wide adhesive long enough to encircle the pelvis

Starting the adhesive from the side opposite the injury draw it snugly and firmly around the injured side of the ilium so as to hold the fragment in position and then anchor the adhesive at the starting point Usually two or three of these strips thus applied are sufficient to immobilize the fragment and maintain position The patient normally may be allowed on his feet in four weeks and the fracture usually is well united in six to eight weeks If it is impossible to reduce the fragment by manipulation, operation is recommended with open reduction and fixation

FIG. 665. (*Left*) Fracture of wing of ilium with some comminution Acetabulum not involved.
FIG. 666. (*Center*) Fracture of wing of ilium with minimal separation Upper edge of acetabulum involved
FIG 667. (*Right*) Comminuted fracture of iliac crest

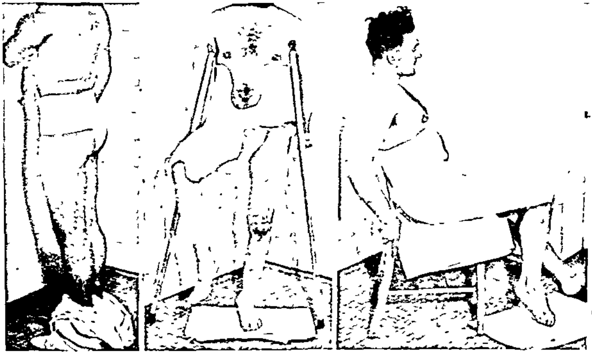
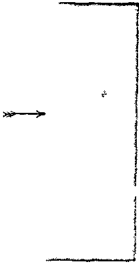


FIG. 668. (*Left*) Adhesive strapping applied for fracture of wing of ilium or iliac crest
FIG. 669. (*Center* and *Right*) Plaster spica for fracture of anterior-superior spine of ilium. (*Center*) Patient ambulatory on crutches. (*Right*) Patient sitting.

FRACTURES OF SINGLE RAMUS OF PUBIS OR ISCHIUM

Fractures of a single ramus of the pubis or ischium are sufficiently splinted by the intact ramus. The only treatment necessary



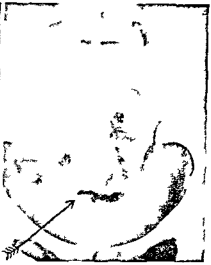


FIG. 670. (*Left*) Fracture of lower sacral segment.
FIG. 671. (*Center*) Fracture of lower sacrum (lateral view).
FIG. 672. (*Right*) Fracture of coccyx.

is complete rest in bed in a recumbent position until the fracture heals. [Where a single ramus is fractured it is possible to keep the patient in bed for only ten days to two weeks and then to allow crutch ambulation for the next four weeks with increasing weight bearing on the affected side gauged by the degree of discomfort experienced, discarding the crutches when little *or no pain is experienced* on full weight bearing. X-ray evidence of healing may be evident in from four to eight weeks.—Ed.] This treatment may be augmented by the application of adhesive strapping around the pelvis as previously described (*Fig. 668*).

FRACTURES OF ANTERIOR SUPERIOR SPINE

Fractures of the anterior superior spine are treated by flexion of the hip on the injured side in slight abduction. When feasible, a plaster spica should be applied to hold the leg in this position until the fracture heals, thus making ambulatory an otherwise bed-ridden patient. [Where the displacement is marked, or where the displacement is only moderate but operative facilities are readily available, operative replacement of the separated spine with wire or fascial loop fixation can be followed by bed rest for ten days or two weeks, succeeded by gradually increasing weight bearing with crutches over the next four to six weeks. No external fixation need then be used.—Ed.]

FRACTURES OF TUBEROSITY

Fractures of the tuberosity are rare and usually require only simple recumbency in bed until thoroughly healed. [Occasionally wide separation of a large shell-like fragment of tuberosity will occur. Time and *certainty of freedom from discomfort* can be gained in these occasional cases by an early operative replacement with fixation by stainless steel wire or fascial sutures. The approach is through the buttock fold. This considerably cuts down the bed rest period necessitated by conservative treatment in these cases.—Ed.]

TRANSVERSE FRACTURES OF SACRUM

Transverse fractures of the sacrum may or may not be dislocated forward. If dislocated, reduction may be readily accomplished by bimanual external and rectal manipulation. Strapping the pelvis by the method described above for iliac fractures, and complete recumbency for from four to six weeks, is advised The use of an inflated rubber ring under the buttocks is advocated when the patient is permitted to sit out of bed. If there is no displacement of the fragment, strapping with adhesive is all that may be required, allowing the patient to go about as usual, using the rubber ring when sitting. [Involvement of the bladder and rectum by sacral-nerve involvement is occasionally seen. In severe cases this may require the treatment accorded "spinal cord" bladder and rectum.—Ed.]

FRACTURES OF COCCYX

The fracture is reduced by rectal manipulation, followed by immediate strapping of the buttocks close together and as low down as possible, extending the adhesive from the region of the anterior superior spine across the buttocks to the opposite anterior spine (Fig. 673). A period of recumbency is usually unnecessary following the above treatment, except in elderly people. The patient is usually immediately relieved of pain. Healing should occur in from six to eight weeks. Weekly strapping is necessary to retain fixation. Occasionally, bed rest for a time may be necessary. Surgical removal of the coccyx is advised only if pain persists for an extended period following conservative treatment.

FRACTURES OF RAMI OF PUBIS AND ISCHIUM

Fractures of the rami of the pubis and ischium, with or without displacement, require only simple treatment. Rest in bed and strapping of the pelvis will usually suffice. These fractures are usually not badly displaced, but if so they can often be replaced in a satisfactory position by manipulation. Rest in bed for a six-week period is necessary, followed by increasing weight-bearing, at first with and then without crutches.

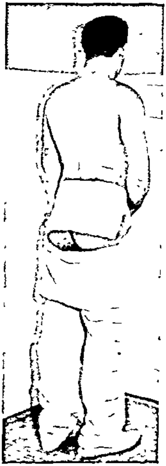


FIG. 673 Strapping for fracture of coccyx. Buttocks are held together tightly.

DISLOCATIONS OF SYMPHYSIS PUBIS AND SACRO-ILIAC JOINT

Dislocations of the symphysis pubis and sacro-iliac joint should be reduced by use of the hammock and extension apparatus as described below (Figs. 677, 678 and 682).



FIG 674 (*Left*) Fracture of right pubic ramus and of left pubic and ischial rami with relatively little displacement

FIG 675 (*Center*) Fracture of left ischial and pubic rami with only moderate displacement

FIG 676 (*Right*) Fractures of both ischial and both pubic rami with but minimal displacement

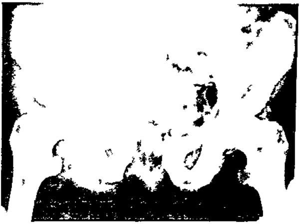



FIG 677 (*Left*) Separation of symphysis pubis—susceptible to treatment by sling suspension

FIG 678 (*Right*) Fracture of pubic ramus with separation at symphysis



FIG 679 (*Left*) Fracture of pubis with separation of symphysis before treatment

FIG 680 (*Center*) Same case as Fig 679 after treatment

FIG 681 (*Right*) Fracture of left ischial and pubic rami and right pubic ramus

FRACTURES OF RAMI OF PUBIS AND ISCHIUM WITH OR WITHOUT DISLOCATION OR FRACTURE OF SYMPHYSIS PUBIS OR SACRO-ILIAC JOINTS

Fractures of the rami of the pubis and ischium, dislocation of the symphysis pubis with or without fracture, and dislocation with or without fracture through the sacroiliac joint—or a combination of any of these fractures—are best treated by suspension in a sling.

Suspension Method of Treatment (Fig. 682). A sling fashioned of adhesive plaster, the average width of which is nine inches and the length of which is 3 to 3½ feet (depending on the size of the patient) can be used. The adhesive is cut to overlap at the ends for a distance of from eight to ten inches. Triangular-shaped sections are cut from each end in such a manner that three tails are formed on each side. One-inch tape is then fastened to each tail. The ends are then dovetailed so that the left side is pointing toward the right side, and vice versa. The ends on either side are then fastened together and attached to a rope running through an overhead pulley on a Balkan frame, above the opposite side of the pelvis The two pulleys are necessary so that in crossing the suspension of the sling as much lateral compression can be given as will be necessary to reduce the dislocation This can be gauged by moving the sides of the Balkan frame closer together for less compression of the pelvis, or farther apart to increase the compression. If compression of the pelvis is not indicated, the extension ropes can be run through the pulleys on their respective sides without crossing the sling The ropes run from the suspending pulleys to the head of the bed passing there through additional pulleys, so that the weights may hang beyond the head of the bed out of the way.

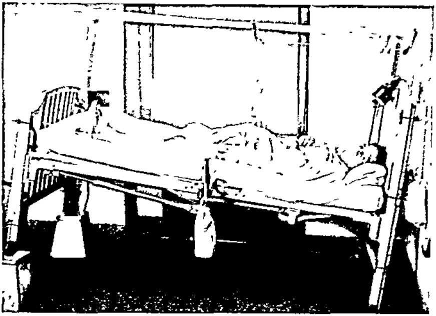


Fig. 682. Sling suspension plus longitudinal and lateral traction for fractures of rami complicated by acetabular fracture

A Buck's extension is then applied in the usual manner to the leg on the affected side. This is accomplished by using two strips of adhesive three inches wide, long enough to go well up into the groin on the inner side

and to just below the trochanter on the outer side and extending for from three to five inches beyond the sole of the foot on either side so that the ends can be made to fasten into a foot piece The adhesive strips should be well bandaged to the leg with gauze or woven elastic bandage Pads of felt or cotton should be placed above the condyles of the femur on both sides and above the internal and external malleoli at the ankle to prevent pressure on the bony parts The bed is then elevated at the foot in order to exert counter traction Ten to 15 pounds of weight are then applied to each leg

The weight required for the suspension of the sling is about 10 to 20 pounds on each side The adhesive side of the sling is next to the patient and assures the same fixation at all times and prevents any shifting

All fractures should be checked at intervals by x ray to determine the position so that changes in traction can be made to influence the position The traction apparatus must be inspected daily for efficiency otherwise failure to obtain reduction may result Careful attention to proper reduction and adequate fixation should give very satisfactory results Treatment of the complications can also be carried out without disturbing the patient

The time required for these fractures to heal can not be stated arbitrarily any more than for other types of fracture but should be governed by intelligent physical and x ray examination in order to determine the degree of fixation and amount of callus deposit Usually eight to ten weeks is sufficient

Before allowing the patient out of bed a belt should be fitted for protection Crutches should be used for the first two weeks out of bed Then exercises such as the proper method of walking and wand exercises with the patient lying face down and on his back should be carried out The patient is usually able to return to work in four weeks after becoming ambulatory a total disability time of 12 to 18 weeks

SEPARATION AT AND FRACTURES NEAR SYMPHYSIS PUBIS

Treatment consists simply of lateral compression which is obtained by use of the hammock apparatus utilizing the Balkan frame (See Figs 677 678 and 682) Operative treatment of these cases is very rarely indicated unless reduction cannot be obtained in any other manner or if excessive motion persists with resultant disability

[Operative repair in these cases is not too simple a procedure It is remarkable how little actual disability apart from a varying degree of waddle in the gait is present in these cases Even when the separation is wide there is little or no pain or discomfort and no economic disability—so much is this the case that the decision to operate requires considerable justification If reduction cannot be obtained by conservative means operative reduction will often prove difficult or impossible and attempts at fascial band or rope silk fixation may be all that can be tried These are not too satisfactory If operative reduction is accomplished fascial suture or bone graft fixation are indicated The approach is suprapubic by transverse incision

A second method of reduction in these cases is that advocated by Watson Jones This consists in manual compression of the pelvis with the patient lying on his side under anesthesia with the application of a plaster spica while in this position —Fd]

Fractures through the sacro iliac joints are usually accompanied by dislocation of the symphysis and fracture of one or both rami Suspension by means of the hammock traction on the leg of the affected side and counter traction by elevation of the foot of the bed are all that is usually necessary Manipulation is considered unnecessary On some neglected cases with a dislocation upward the fragments fail to unite properly In these cases a fusion operation on the sacro iliac joint is indicated While the operation is being performed enough trac

tion should be maintained on the leg of the affected side to pull the ilium into as nearly normal position as possible; counter-sinking of the block of bone then holds the position effectively. [See Chapter 15 for sacro-iliac fusion.—Ed.]

DOUBLE VERTICAL FRACTURE OF MALGAIGNE

The double suspension and traction on the leg of the affected side is indicated, being careful to apply sufficient weight to the leg to pull the pelvis into proper position. The amount of weight necessary can be gauged by x-ray. Usually 20 to 25 pounds is sufficient. This position is maintained until the fracture is thoroughly healed. The healing time required varies, but ten weeks are usually sufficient.

In all severe fractures of the pelvis, the wearing of a supporting belt is advisable for two or three months after the patient becomes ambulatory.

Operative Reduction. In my opinion, operative reduction is only necessary in those cases in which dislocation of the symphysis and sacro-iliac and fracture of the ramus occur which cannot be reduced with the suspension and extension apparatus on account of a prolonged critical general condition. The unreduced case, in our experience, always has pain and disability unless it is reduced and fixed by operation. The type of operation which the author has used in two such cases has been very satisfactory.

Operation. An incision six inches long is made over the symphysis, exposing the unaffected side. Dissection is then made down to the dislocated portion of the symphysis. This is grasped with bone-holding forceps and pried into position with a skid. Holding the corrected position with forceps, a hole is drilled through the symphysis from one side to the other, crossing the joint. A fairly large dowel graft, about five-eighths of an inch in diameter, is pounded or inserted through the drill hole from one side into the other for a distance of one and one-half inches. The bone dowel should be fairly thick and strong in order to withstand the pressure and to prevent re-dislocation Small bone chips should be placed between the opposing surfaces of the symphysis after removal of the cartilage as there is apt to be a slight separation of one-eighth to three-sixteenths of an inch. The incision is closed in the usual manner. After dressing the wound, a tight adhesive strapping is applied, starting the adhesive well posterior to the anterior superior spine and crossing the front of the pelvis to well posterior to the anterior superior spine on the opposite side, in such a firm manner as to further draw the symphysis together. To further augment the security of the pelvis, two weeks later, a sacro-iliac fusion is done.

FRACTURES OF ACETABULUM

Fractures of the acetabulum with displacement of the fragment and of the head of the femur upward or posteriorly outside the pelvis are best treated by means of traction and a plaster-of-paris hip spica. The extension straps are placed and the plaster is applied over sheet wadding which is rolled on the leg very loosely so as not to interfere with the pull on the leg. A 10- or 15-pound weight is used on the straps emerging from the lower end of the spica, with only a slight amount of counter-extension being necessary. Six to eight weeks are required for healing. The patient is then allowed up, and is permitted to walk on crutches, and the healing is checked by means of x-ray. In a few of these fractures a closed reduction cannot be obtained because of a fragment in the acetabulum which holds the head out of position. With this type it is necessary to open the joint and remove the fragment which is preventing the head from sliding into position. After operation, traction in a plaster-of-paris hip spica is applied and the fracture is treated in the same manner as previously

described [Well leg traction either of the Hoke type or that utilizing skeletal traction or skeletal traction through the lower femur or the tibial tubercle or Russell traction can be utilized in these cases For the technic of these procedures see Chapters 22 and 35 —Ed]

FRACTURES OF ACETABULUM WITH PROTRUSION OF HEAD INTO PELVIS

Lateral traction placed high in the groin is indicated It is obtained by using a well padded swathe of muslin or canvas about four to five inches wide running around the thigh and attached to a rope running through a pulley at the side of the bed A Buck s extension with a small amount of weight eight to ten pounds should be applied for fixation of the leg and a 15 to 25 pound weight should be applied to the lateral traction A swathe can be run around the pelvis and fastened to the opposite side of the bed to prevent shifting of the pelvis (Fig 686)

Some prefer running a wire anteroposteriorly through the trochanter and applying lateral traction through the attached yoke the principle being the same Manipulation under anesthesia with slight flexion and external rotation with an assistant pulling outward on the upper portion of the thigh so as to act as a fulcrum while the lower end of the femur is adducted will often effect a reduction Constant lateral traction should be maintained after reduction

[*Other methods of reduction may be* used The Whitman procedure as used in reductions of hip fractures is often successful in reducing the head from its intrapelvic position It is best followed by one of the methods of continuous lateral traction for maintenance of the reduction Cubbins secures lateral and downward traction through a large screw inserted laterally through the trochanter well into and in the line of the femoral neck Adduction of the lower femurs while a padded object roughly the size of a small leg is held between the upper thighs (Jones) is often effective A wedge may similarly be used or plaster encasement of the thighs with an interposed turnbuckle may apply the same principle

After reduction by any of these methods some men prefer to hold the position by the application of a plaster spica It is probably better however to follow reduction by one of the methods of continuous lateral and downward traction until healing of the fractured acetabular floor is well established This will take usually 8 to 12 weeks The patient can then be allowed up and motion in the joint can be allowed but weight bearing on the affected side should be avoided by the use of crutch ambulation



FIG 683 (*Left*) Fracture of acetabulum with minimal displacement
FIG 684 (*Center*) Fracture of acetabulum involving ischium
FIG 685 (*Right*) Fracture through acetabulum with beginning intrapelvic protrusion of femoral head

or by a *non-weight-bearing brace on the* affected side with a high-soled shoe on the *sound side for the next four to eight weeks* or longer, depending upon the x-ray evidence *of solidity and density of healing.* (See Chapter 14 for type of brace.)

that period of time. If such changes do occur, with resultant pain and stiffness, the procedures *advised in* Chapter 15 *for ar*thritis of the hip joint must be considered. —Ed.]

In irreducible fractures of this kind, al-

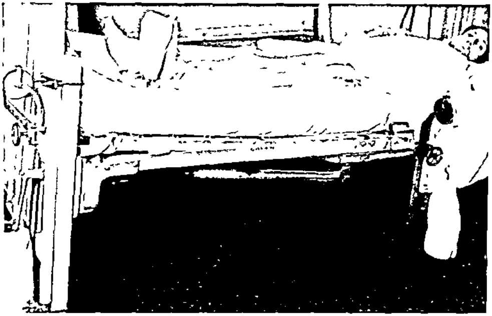


Fig. 686. Longitudinal and lateral traction for fracture of acetabulum with intrapelvic protrusion of femoral head. For fracture of acetabular rim with or without subluxation of femoral head outside pelvis, longitudinal traction alone may be used.

In many of these cases, the head can be reduced from its intrapelvic position, but because of comminution and lack of softpart attachments the acetabular floor fails of reduction either partially or completely. Even so, the treatment as described should be continued until good healing is secured (see below).

It should be remembered that late degenerative changes in the hip joint may occur following this type of injury, and a guarded prognosis is wise even though the primary result from an anatomic and functional standpoint may be good. Since these changes may take from one to four or five years to develop, the patient should be advised to undergo a check by clinical and x-ray examination at yearly intervals for

low them to heal firmly. After firm healing, a plastic operation is done on the superior rim of the acetabulum if motion restriction and pain warrant it. Excision of that portion of the rim preventing motion will give a good functional result One of our cases done in 1923 in this manner has been very satisfactory. [See acetabuloplasty, Chapter 15, and see also the editorial note immediately preceding.—Ed.]

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28

Injuries to Ribs, Costal Cartilages, Sternum, and Sternoclavicular Joint

HARRISON L. McLAUGHLIN, M.D.

CONTUSIONS OF CHEST

A contusion of the expansile portions of the thoracic cage, whether or not it is accompanied by roentgen evidence of a fracture, from the patient's point of view is frequently just as troublesome as a definite fracture. One reason for the frequency of this finding is the difficulty in demonstrating an undisplaced fracture of a rib by x-ray in the early stages, and not until subsequent films show callus formation surrounding a rib at the site of the previous injury is it realized that the diagnosis should be changed from contusion to fracture. Any contusion giving severe symptoms warrants the same therapy as would be accorded a definite fracture, and in equivocal lesions the x-ray report is to be disregarded as a factor in determining the necessary treatment.

Complications. Contusions are not always uncomplicated. When they occur over the hepatic or splenic area it is necessary to keep in mind the clinical evidence to warrant suspicion of such an injury. A severe contusion of either region followed by an acute abdomen with a progressively falling blood pressure and red-cell count, and a pulse that becomes progressively more rapid and weak in spite of anti-shock measures, warrants exploration of the abdominal cavity without delay unless these signs can be explained on a basis other than that of a ruptured viscus. In the presence of signs that are equivocal, the wisdom of taking a lateral x-ray of the spine in order to rule out retroperitoneal hemorrhage resulting from compression fracture of a vertebral body is at once apparent.

Sequelae. Occurring over the lung area, a contusion may result in pleuropulmonary trouble without producing any fracture. Evidence of a localized underlying pleurisy, either dry or with effusion, is not infrequently present. Occasionally a localized atelectasis may develop underlying the site of a contusion and may be followed by bronchitis or pneumonia in the region involved. All such complications constitute indications for specific therapy.

FRACTURES OF RIBS

Fractured ribs require no treatment to insure solid union, which may be expected with complete confidence The associated symptoms and complications constitute and include all the indications for therapy, and the fracture, per se, may be disregarded unless it is such that its physical characteristics have a direct bearing on some symptom or complication—e g., pressure resulting from gross displacement of a fragment.

RELIEF OF PAIN

The all-important symptom is pain, aggravated by coughing, breathing, and any motion involving the chest wall.

Nature s Method of Therapy This consists of voluntary restriction of his activity by the patient and involuntary splinting of the thorax and to a lesser extent the abdomen by the muscles Both processes are useful tending to diminish the pain Both are somewhat harmful since the net result of restriction of activity is disability To reduce this disability to a minimum becomes one of the most important aims of treatment The net result of thoracic splinting by muscle spasm is reduction of available pulmonary ventilation and a predisposition to pleuropulmonary complications Therapy producing effective relief of pain is the solution of both problems

External Supportive Dressing In the ordinary ambulatory patient suffering from a severely contused chest or uncomplicated rib fractures this is most efficiently applied in the form of an external supportive dressing Such dressings may be of various types and can be made of divers materials but in the final analysis must accomplish their purpose by means of mechanical restriction of thoracic excursion

Figs 687 688 and 689 represent three styles of thoracic dressings and the one of choice in any given case is to be determined by a consideration of the severity of the symptoms the age the sex and the build of the patient No such dressing should completely restrict thoracic excursion The more tightly a dressing is applied and the more rigid it is made the more handicap to adequate pulmonary ventilation is created The optimum dressing is that which produces maximum relief of pain and minimum restriction of the normal physiologic functions of the thoracic cage

Adhesive strapping applied directly to the skin at as nearly as possible 90° to the long axis of the ribs and extending several inches above and below the painful area is easily applied and gives adequate relief in those cases suffering from mild pain

Before application of the adhesive the skin should be shaved when necessary, and coated with tincture of benzoin compound The patient should be made to hold the arms akimbo and to exhale prior to the application of each strip of adhesive and *each strip should extend well past the mid* line both anteriorly and posteriorly as in Fig 687 The strips should be laid on in exhalation and not applied with further constricting force Such a dressing has the advantage of producing a minimum of thoracic restriction but by the same token gives relatively little relief to a patient who is suffering really severe pain

In women particularly when the breasts are pendulous its application is difficult and the amount of relief obtained is insufficient to compensate for the misery produced by wearing it and to any patient its presence is particularly intolerable in hot weather Consequently the choice of this type of dressing is ill advised during hot weather or in women and also in any person suffering severe pain or in whom it is apparent that support will be required for more than a few days

For the relief of pain in the average uncomplicated case a complete encirclement of the thorax in exhalation by adhesive strapping applied over an insulating layer of flannel bandage (Fig 688) will be found to satisfy the requirements of comfort and wearability Such a dressing has the advantages of protecting the skin allowing adequate ventilation and also giving more efficient symptomatic relief than the application of adhesive directly to the hemithorax

In order to prevent wrinkling of the dressing and to maintain it at the desired level it is necessary to hold it up with suspenders of any soft bandage material which are fastened to the main dressing by safety pins However the same type of dressing using any one of the bandages that is both elastic and adhesive instead of ordinary adhesive plaster is even more efficient in that it will give as much relief and produce less constriction

A thin but rigid dressing can be made

with plaster of paris carefully molded to the thorax in the form of a Sam Browne belt (Fig. 689). Such a support is rarely necessary unless rigid protection of the thoracic cage is desired, or in fractures of the upper two or three ribs requiring stabilization of the lower mobile portion of the thoracic cage as well as an additional support molded over the involved shoulder.

RELIEF OF PAIN BY NERVE BLOCK

In a selected group of cases, particularly in multiple lesions of more serious import or in elderly persons prone to pulmonary stasis if bedridden, an external dressing in order to be adequate from the viewpoint of symptomatic relief must be applied so tightly that it over-restricts thoracic excursion. This effect is contraindicated by the threat of pleuropulmonary difficulties. The most efficient prophylaxis against the latter complication is maintenance of both pulmonary ventilation and the ability to cough. In severe injuries or in elderly persons the restricting powers of any dressing should be minimal. Opiates favor neither ventilation nor coughing, and should also be curtailed as much as possible. The best way of maintaining active thoracic ventilation and coughing power coincident with elimination of pain is by actual interruption of the pain stimuli by nerve block. Merely as an auxiliary measure, often unnecessary, a light and relatively unrestricting external support can be applied.

Neotheosol. The most prolonged anes-

Fig. 687

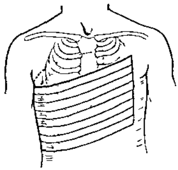


Fig. 688

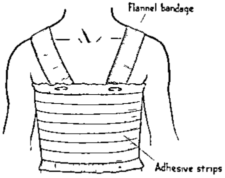
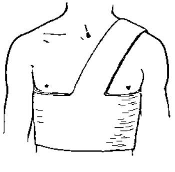


Fig. 689



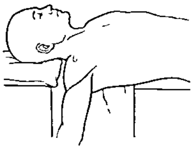


Fig. 690

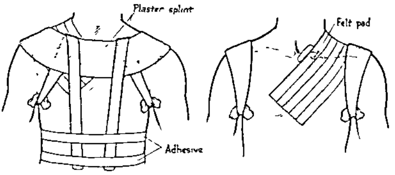


Fig. 691

Fig. 687. Adhesive strapping used as a thoracic bandage.
Fig. 688. Adhesive strapping applied over an insulating layer of flannel.
Fig. 689. Plaster bandage molded to thorax. The form is that of a Sam Browne belt.
Fig. 690. Maneuver for dislocation at sternoclavicular joint.
Fig. 691. Dressing for dislocation.

thetic effect is obtainable by the injection of neotheosol but the use of any such heavy solution entails the risk of a severe local inflammatory reaction if more than 1 cc is allowed to collect in a single tissue region This reaction is marked by redness swelling pain tenderness and at the site of the injection local heat of sufficient intensity to defeat the main purpose of the injection It is frequently accompanied by fever increased pulse rate leukocytosis and general malaise but while these manifestations may be severe they are as a rule transitory and require nothing except bed rest and sedation for their control Such a reaction has no permanent harmful effects and seldom lasts for more than 48 hours

Procaine Hydrochloride Procaine hydrochloride in a 1 or 2 per cent solution depending upon the volume to be injected is advised The intercostal nerves at the site of pain only may be anesthetized with moderate though transient relief of symptoms but the blocking of several nerves above and below the site of pain is often necessary before adequate symptomatic relief is obtained

Injections should be made into the intercostal spaces at points posterior to the actual sites of fracture and should be a little posterior to the points of emergence of the lateral cutaneous nerve branches The needle should be inserted to contact the rib above the space to be infiltrated and its point then carried gently downward following the outer aspect of the rib to its lower border then to the interosseous space As the needle is felt to reach the lowermost edge of the rib an aspiration test should be carried out with the needle rotated in two planes in order to make certain that an intercostal vessel has not been punctured From 2 to 4 cc of the anesthetic solution may then be slowly injected this amount should prove adequate for temporary blockage of the intercostal nerve

During the course of such a procedure signs of pleural or pulmonary puncture such as a sudden coughing spasm or a bitter taste in the mouth have been reported but if care is taken to maintain the needle point in close contact with the rib and to insert it no farther than the lowermost palpable edge of the bone the danger of such puncture is remote

Paravertebral Block Paravertebral block of the intercostal nerves gives a more prolonged and efficient anesthesia and has the advantage of being removed from the site of local tissue injury The best procedure is probably the Labat No 1 technic

The patient is placed on the uninjured side knees and hips flexed to widen the intercostal spaces With procaine hydrochloride a skin wheal is raised 4 to 5 cm lateral to each spinous process corresponding to the intercostal spaces selected for injection If a small nick is then made with a sharp pointed scalpel through the skin in each wheal the insertion and control of the injecting needle will be more easily accomplished The needle should be of 20 gauge caliber and from 8 to 10 cm in length It is inserted through the skin nick at right angles to the skin to hit the surface of the rib lying just above the space to be infiltrated The handle of the syringe should then be tilted outward and upward toward the shoulder on the affected side to make an angle of about 45° with the skin surface and the needle is slowly advanced inward and downward for about 1 cc until it is felt to slip off the lower border of the rib Maintaining the same direction if the needle is then further advanced for another 2 cm or so it will be felt to impinge against the body of the vertebra

The entire procedure should be carried through with the utmost gentleness and if the directions are adhered to repeated aspiration tests will be sufficient to eliminate the possibility of a mishap

The point of election for the injection of the anesthetic agent *is that at which the* needle impinges against the vertebra A solution of procaine hydrochloride stronger

than 1 or 2 per cent may have toxic effects, and a weaker solution requires the injection of too great a volume of the agent, but 5 to 6 cc. of a 1 or 2 per cent solution, if correctly placed, will diffuse sufficiently to produce anesthesia of the anterior and posterior primary divisions of the nerve as well as of the communicating rami. As a general rule, unless three or less intercostal spaces are to be injected, the 1 per cent solution should be used. This procedure will produce up to 12 hours of marked symptomatic relief, during which time the patient can be moved about with little discomfort, and during which respiration and cough are not unduly curtailed by pain. When this period of relief has passed, if the indications are still present, reinjection may be done. Not infrequently it may be necessary to repeat the procedure several times on succeeding days.

At times, because of age and imminent threat of pneumonia, multiple injuries, shock, or dangerous respiratory embarrassment due to pain and muscle spasm, the period of symptomatic relief obviously necessary will greatly exceed that obtainable by the use of procaine and its use will entail many injections. In such selected cases the gravity of the situation constitutes an indication for more prolonged anesthetic effect. This may be had by injecting about 1 cc. of 95 per cent absolute alcohol into each interspace directly following the commencement of the procaine effect.

A certain number of dangers attend this use of alcohol and it should be considered as not without risk, especially in inexperienced hands. The technic of the injection is unchanged, but the injection of alcohol should always be preceded by the procaine block, using 3 to 4 cc. rather than 5 to 6 cc. of the anesthetic, and the amount of alcohol should not exceed 2 cc. in volume for any one interspace, nor should it ever be injected until the anesthetic effect of the procaine is established.

The result to be expected is a paralytic and anesthetic effect that lasts for several weeks. Some of the smaller sympathetic rami may never regain their function following exposure to alcohol but the main paralytic effect is seldom observed to last more than about three weeks.

Dangers Attending Injection. The dangers attending the actual technic of injection include pleural, pulmonary, blood-vessel, and subarachnoid puncture. With the use of procaine the possibility of any serious or permanent trouble is remote even in the event of an inadvertent puncture of one of these structures, but it will be obvious that the misplacement of a significant quantity of alcohol carries serious potentialities.

Pleural Puncture. If done with a small-bore needle, pleural puncture will not result in a pneumothorax, and the presence of procaine in the pleura will do no harm If procaine is accidentally placed in the pleural space the result will be a fit of coughing, and such a sign during the course of an injection procedure is the indication for cessation of injection and realignment of the needle. Alcohol in the pleural space is characterized by a severe localized burning pain which occurs as soon as the anesthetic effects of the procaine wear off. The result is a localized chemical inflammation that is more severe from a symptomatic viewpoint than it is serious.

Lung Puncture. This will ordinarily be preceded by the signs of pleural puncture if the injection is done as slowly as it should be. It is characterized by a bitter taste in the mouth due to procaine in the lung, and by the appearance of blood by aspiration. Unless the operator disregards these signs and persists in the misdirected injection, no harm will ensue.

Blood-vessel Puncture. Blood-vessel puncture with a small-bore needle is a remote possibility, and is easily avoided by repeated aspiration tests in two planes. The most serious result of such an incident will be the formation of a small hematoma of no clinical significance.

SUBARACHNOID PUNCTURE Subarachnoid puncture through the intervertebral foramen is almost impossible if the described technic is carefully followed It must be borne in mind, however, that the subarachnoid space may be entered and spinal fluid withdrawn by puncturing a prolonged cul de sac surrounding the nerve root as it emerges from the spinal canal Aspiration tests prior to the injection of solution should always be done to eliminate this possibility, because, while the injection of procaine into this space may have alarming if only transient results, the injection of alcohol has been known to produce some unhappy and avoidable disasters

The injection of alcohol, even when properly placed is not always free from untoward results Not infrequently it is followed by an irritation neuritis of the corresponding somatic nerves, and this symptom may not only be troublesome enough to require control by repeated procaine injections but also may persist over the course of many weeks Consequently, alcohol must be considered as an agent to be used only when the indications are imperative, and then only by the surgeon who is both skilled in the technic of its use and *prepared to cope with any undesired results* that may ensue

COMPLICATIONS OF FRACTURED RIBS

The complications of fractured ribs are potentially numerous and constitute therapeutic indications of much greater importance than usually arise from the fractures, per se

Pleurisy Pleurisy is common, it may be of a dry type or characterized by effusion Effusions resulting from purely traumatic causes should be emptied only to relieve pressure symptoms (such as marked dyspnea, tachycardia, and mediastinal displacement), but any appreciable volume of pleural fluid warrants a diagnostic puncture Whether the fluid proves bloody or clear there is frequently an accompanying low grade temperature and no such patient should be allowed out of bed until the fluid has absorbed and the temperature has remained normal for a week or so The temperature reaction in a pleurisy of purely traumatic etiology will usually subside within the course of a week or ten days

Pneumothorax Pneumothorax occasionally assumes alarming proportions especially in the sucking or ball valve type of lesion which produces a progressive elevation of intrapleural pressure and a secondary displacement of the mediastinal structures The clinical result is a combination of circulatory and respiratory embarrassment severe enough to demand prompt deflation of the pneumothorax by repeated aspirations or by a closed system of catheter drainage Subcutaneous emphysema may be marked When the pleural tear occurs on the mediastinal surface, this emphysema, after working its way upward along the mediastinal alveolar planes and the route of the carotid sheath will first become apparent in the neck Occasionally, but very rarely, incision of the neck is necessary before mediastinal deflation can be accomplished

Hemothorax This is common in severe *injury and depending on the severity of the* injury and the amount of blood loss may or may not be accompanied by shock If the amount of blood in the pleural cavity is small it should not be disturbed but any hemothorax of significant amount should be aspirated and replaced by two thirds of an equal volume of air to preserve the tamponade effect If a large amount of blood is allowed to organize in the pleural cavity a marked pleural thickening is prone to occur, at times sufficient to prevent reexpansion of the lung Such a fibrothorax is sooner or later characterized by cicatricial retraction and may result in a late empyema or bronchiectasis in the adjacent lung tissue

Intercostal Hemorrhage Although common, intercostal hemorrhage is rarely of a

sufficiently severe degree to warrant specific therapy or consideration as a complication.

Pulmonary Hemorrhage. This is present to some degree in every lacerated lung, but the spontaneous collapse produced by the laceration is almost always sufficient to control it adequately.

Pneumonia. Pneumonia is always a potential complication, particularly in bedridden or elderly patients, and its optimum therapy is prophylactic in nature. This has already been discussed. While the relief of pain is probably the most important factor in the accomplishment of this prophylaxis, the use of carbon dioxide is at times necessary to enforce deep breathing, and oxygen may be useful in helping to produce maximum aeration with a minimum of effort. Once established, pneumonia becomes the therapeutic problem of primary importance and the rib fracture should be relegated to the position of a complication deserving of active treatment only when its presence interferes with the course of treatment of the pulmonary condition.

Paralytic Ileus. Occasionally paralytic ileus occurs; it should lead to an immediate suspicion of intra-abdominal injury, although this is not always the case. Autopsy examinations of ileus patients have been occasionally reported as negative for any evidence of traumatic pathology except fractured ribs.

Late Compression Neuritis. Late compression neuritis by pressure of contiguous callus is sometimes encountered, especially following lesions of the proximal portions of the upper three ribs. The resultant clinical syndrome is inclined to be somewhat vague due to the varied number and distribution of the nerves that may be affected, and for this reason the basic site of pathology is often hard to localize. It is difficult to obtain adequate x-rays of the proximal portions of the upper ribs, and in such a case (which may present the picture of wryneck, a neuritic type of pain radiating from the neck along the upper extremity, atrophy and weakness of various groups of muscles in the extremity, and poorly localized sensory changes), a clear roentgenologic demonstration is all-important in the establishment of the primary etiology. Such cases constitute a neurosurgical problem of no little difficulty.

Severe Crushing Injury with Multiple Fractures, Acute Pleuropulmonary Complications and Shock. The most difficult therapeutic problem occurring with fractures of the ribs is that resulting from a severe crushing injury with multiple fractures, acute pleuropulmonary complications, and shock. Frequently the treatment of this type of case is made more difficult by the presence of additional injuries to the cranium, spine, or extremities.

In any severe thoracic injury the head of the bed should be elevated to the point of maximum comfort of the patient and a fracture board inserted under the mattress. Transfusions or administrations of fluids parenterally should be done in accordance with the indications of the hematocrit and plasma-protein findings. Body temperature must be maintained and adequate sedation administered in accordance with the demand. Hemo- or pneumothorax should be relieved if productive of circulatory or respiratory embarrassment. Paravertebral block is usually indicated when or if the patient's general condition permits, and the chances of maintaining adequate pulmonary ventilation with a minimum of effort are greatly enhanced by the use of an oxygen tent.

If there is an accompanying fracture of the sternum with a fragment so depressed that venous obstruction is produced in the superior mediastinum, the depressed fragment should be elevated, but the fractured ribs, per se, unless gross displacement appears to definitely interfere with the necessary treatment of the pleuropulmonary condition, usually warrant no active treatment other than stabilization by sandbags or a light binder.

Once the patient is out of immediate danger the subsequent therapy should be designed to minimize or prevent the occurrence of further complications and to control whatever pleuropulmonary condition results from the original injury

FRACTURES OF STERNUM

Fractures of this bone are rare They usually occur in the region of the junction of

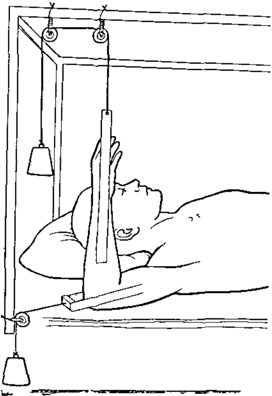


FIG 692 Side arm traction applied for *minimizing of residual deformity*

manubrium and gladiolus, and when undisplaced warrant no treatment other than control of pain and stabilization of the thoracic cage by some form of binder The prognosis is good, and as a rule symptomatic recovery is complete within the course of several weeks

Occasionally such a fracture may be displaced, the displacement is almost always characterized by a depression of the lowermost fragment This displacement is often spontaneously corrected by a sneeze or a cough on the part of the patient, or if not, can usually be reduced by hyperextension of the dorsal and cervical spine over the edge of a bed or table If such a maneuver fails it may at times be necessary to perform a direct elevation of the depressed fragment through an operative incision particularly when there are signs of superior mediastinal venous obstruction e g cyanosis and petechial hemorrhages in face and neck, or when the optimum cosmetic result is demanded

Once reduction has been accomplished no dressing other than a light binder is necessary, and whether or not bed rest is needed depends entirely on the severity of symptoms and the presence or absence of mediastinal complications In the absence of pressure symptoms reduction of the depressed fragment is essential only from the viewpoint of the cosmetic result, and while elimination of the bony deformity is desirable in all cases, and particularly desirable in women, no harmful result except deformity will ensue if such a fracture is allowed to heal in an unreduced position

DISLOCATIONS AT STERNOCLAVICULAR JOINT

Dislocations at this joint are characterized by a displacement of the inner end of the clavicle that is always slightly upward and, in addition, either forward or backward in relation to the sternum In cases having an *anterior displacement* the deformity is quite apparent, and as a rule easily reduced Those with posterior displacement are a little less obvious of diagnosis, and, although easily reduced, are somewhat more serious in their clinical implications because once the inner end of the clavicle commences to slip backward it produces pressure symptoms, primarily on the trachea and later on the superior mediastinal vessels Consequently in this type of lesion the alarming clinical picture of extreme dyspnea and cyanosis is not rare

and calls for immediate relief of the mechanical obstruction by reduction of the dislocation.

In either type of displacement reduction is easily accomplished by traction on the shoulder in a direction parallel to the long axis of the clavicle, i.e. outward, backward, and slightly upward. This maneuver is more easily accomplished if the patient is placed on his back with the arm hanging over the side of the bed or by placing him in a position similar to that illustrated in Fig. 690. This position has certain advantages in that it utilizes the weight of the involved arm to assist in the traction necessary for reduction, the weight of the other arm for balance, and their combined weight in assisting to maintain reduction during the application of a splint. In addition, the shoulders are left free to be splinted without any undue motion or disturbance of the freshly reduced lesion.

Attempts to maintain reduction merely by the use of a pad and adhesive strapping over the injured joint, no matter how tightly applied, are useless. Maintenance of reduction is difficult in all cases and the only efficient dressing is one that holds the shoulders upward, outward, and backward so that the weight of the extremity pulling downward on the outer end of the clavicle, and thereby levering the inner end out of position over the fulcrum of the first rib, is minimized.

Adequate dressings for this purpose are similar to the type of dressing used in fractures of the clavicle, and may be fashioned of plaster-of-paris splints molded to the shoulders as in Fig. 691, or of wood or metal in the form of a clavicular cross. Such a dressing should be worn for at least four weeks and should be followed by an additional period of restricted activity of several weeks' duration.

In women, where the cosmetic result is of major importance, and when economic circumstances permit, complete bed rest for three to four weeks with continuous side arm traction as in Fig. 692 offers the optimum chance for the lesion to heal with a minimum of residual deformity.

Operative Repair. Operative repair of a dislocation at this joint is indicated when adequate maintenance of reduction cannot be secured by conservative methods and when subsequent slipping and clicking in the joint, even though painless, have caused the patient sufficient bother and inconvenience to warrant such a procedure.

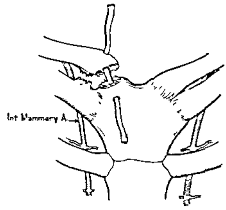


Fig. 693. Strip of fascia or tendon used to repair torn ligaments.

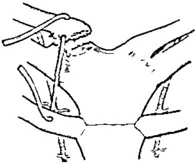


Fig. 694. Another method of repairing a torn ligament.

The deranged joint should be exposed on its anterior surface and the articular fibrocartilage removed. In order that a fibrous union may occur between the two bones the cartilage should also be removed from the articulating surfaces of both sternum and clavicle. Inasmuch as secure stabilization by direct repair of the torn ligaments is

very difficult the reduced joint should be supported by a strip of fascia or tendon, passed through both bones as in Figs 693 or 694 Great care should be taken during *the course of any surgical procedure in this* region to protect from damage the superior mediastinal structures which are closely approximated to the posterior surface of the joint

Postoperative treatment should include a preliminary period of two weeks during which the patient is kept in bed with the extremity suspended as in Fig 692 followed by another period of at least four weeks during which the patient may become ambulatory but in which the repaired joint is protected from excess strain by a dressing similar to that shown in Fig 691 All protection may then be removed and the patient allowed to resume normal activities progressively [Excision of the inner two inches of clavicle subperiosteally is a simple way of dealing with these dislocations It occasions no disability no loss of *stability in the shoulder girdle and pro*duces no deformity of any note Function can be resumed when the wound is healed —Ed]

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SECTION TEN

FRACTURES AND DISLOCATIONS OF UPPER EXTREMITIES

29

Injury to Shoulder Girdle

HENRY C MARBLE, M D

From the surgeon's point of view, the shoulder girdle consists of (1) the clavicle (2) the scapula and (3) the upper end of the humerus In reality it is not a girdle at all because the scapulae do not unite in the back and the clavicles are separated in front by the sternum The clavicle attaches the shoulder to the chest and at the same time holds it away from it

The clavicle is attached to the sternum by firm ligaments forming the sternoclavicular joint to the acromion process of the scapula by the acromioclavicular ligaments, to the coracoid process directly below it by the strong coracoclavicular ligaments, and to the first rib by the subclavian muscle and the rhomboid ligament (Fig 695)

Mechanically the bony structure of the shoulder joint is weak Its strength is obtained from the strong muscles which surround and protect it, particularly above, anteriorly, and posteriorly It is further protected from injury above by the overhanging acromial process The capsule of the shoulder joint above, anteriorly, and posteriorly is intimately connected with and reinforced by the short rotators of the shoulder—the subscapularis in front, the supraspinatus above, and the infraspinatus and teres minor posteriorly and below It is protected in front by the pectoralis major, the latissimus dorsi, and the teres major The long tendon of the biceps, arising from the upper rim of the glenoid, passes through the joint and then through the bicipital groove, anterior to the greater tuberosity and down the arm to form one anchoring attachment of the biceps muscle Over all the joint is covered and protected by the large deltoid muscle (Figs 696 and 697)

The subdeltoid bursa, like a large deflated balloon, is deep to the deltoid muscle and superficial to the muscles and tendons forming the upper part of the capsule of the joint It permits separate function of the definite layers of muscles in abduction, flexion extension, and rotation

The upper end of the humerus is much larger than the glenoid and is held in place in the glenoid only by the action of the strong muscles described above It is protected superiorly by the acromion process which has an articular facet on its lower surface The shoulder girdle as a whole is elevated by the trapezius muscle and depressed by the latissimus dorsi Passing through the axilla, under cover of the shoulder girdle, are the brachial plexus, the brachial artery, and the brachial vein The clavicle is the inner prop of the shoulder girdle (Fig 698)

CLAVICLE

Fractures of Clavicle These usually occur in the outer half of the bone, and 65 per cent occur in the first two decades of life Fractures from direct violence are unusual, and compound fractures are very rare Following fracture, the proximal fragment is firmly fixed and the outer fragment

is displaced downward and forward by the weight of the extremity. X-ray examination should be made to determine whether or not there is injury to the distal and proximal joints. Clinical examination should exclude damage to the brachial vessels and nerves.

TREATMENT. The function of the clavicle is to aid in holding the shoulder upward and backward. With a fracture this power is lost. The logical treatment is to restore it. This is best accomplished by sitting the patient upon a low stool, standing behind the patient and putting the knees between his shoulder blades, grasping the heads of both humeri with the hands, and gently lifting upward, outward, and backward. This reduces the fracture The problem now is to devise some apparatus which will hold the shoulder in this position. Any device that does this without abolishing shoulder function is good treatment.

TYPES OF APPLIANCES USED Following are types of appliances used:

1. A T-shaped splint, with the shoulders fastened to the crossarm and the vertical arm applied to the back (Fig 699). This splint may be of wood, well padded, or of metal. In the latter instance the vertical arm can be molded to the curves of the back. It should be applied with the arms held in right-angled abduction and with the shoulders held back in the position which secures adequate reduction The crossarm is applied first, as illustrated in Fig 699, and the vertical arm is then carried down and fastened. The structures in the axilla must be protected by adequate padding of the bands which fasten the shoulders to the crossbar. If a straight wooden or metal vertical bar is used, the space between it and the patient's spinal curve should be filled with firm padding. The lower end of the vertical arm must be kept in the midline by adhesive strapping or by adequate bandaging. Frequent observation is necessary to preclude inordinate pressure on the vessels and nerves in the axilla, or undue loosening of the axillary bands allowing sagging of the shoulder. Active motion is encouraged from the beginning, with perhaps the wearing of a sling for the arm of the affected side for the first ten days or two weeks The splint should be worn for from four to six weeks—until x-ray and clinical evidence of union are present. At this time full shoulder function should be present, and no after-treatment should be necessary.

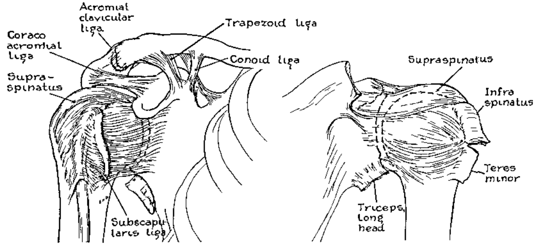


FIG 695 Ligaments of shoulder joint as seen from front and back

2. A simple shoulder brace of metal-reinforced leather and webbing that holds the shoulders upward, outward, and back

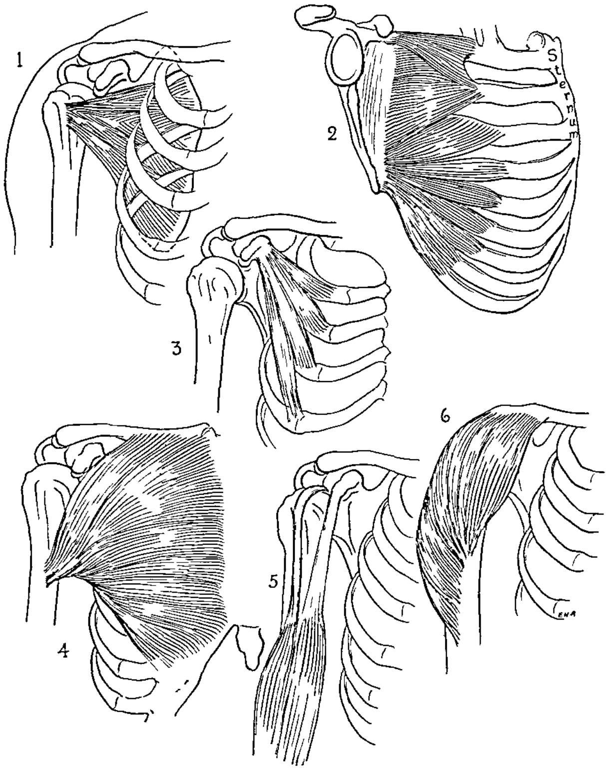


FIG 696 Muscles of shoulder girdle from in front (1) Sub capularis, (2) serratus anterior, (3) pectoralis minor, (4) pectoralis major, (5) biceps brachii, (6) deltoideus (anterior portion)

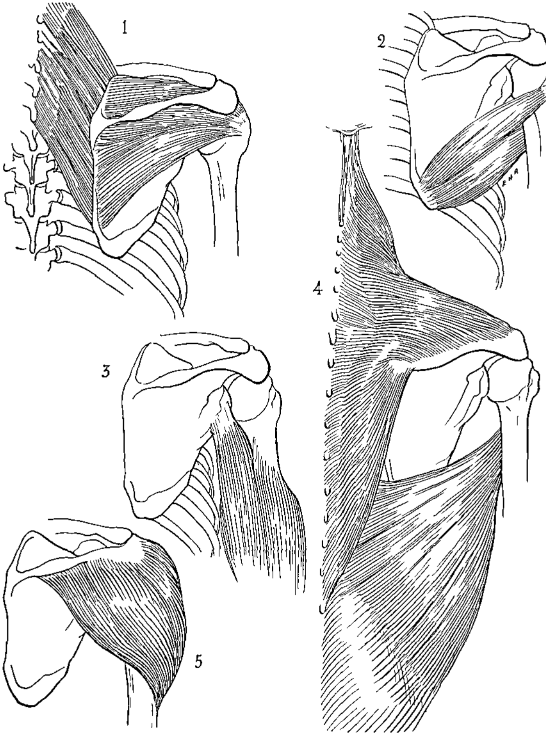


FIG. 697. Muscles of shoulder girdle from behind· (1) Rhomboideus minor and major, supraspinatus and infraspinatus, (2) teres minor and major, (3) triceps brachii, (4) levator scapulae. trapezius, and latissimus dorsi, (5) deltoideus (posterior portion).

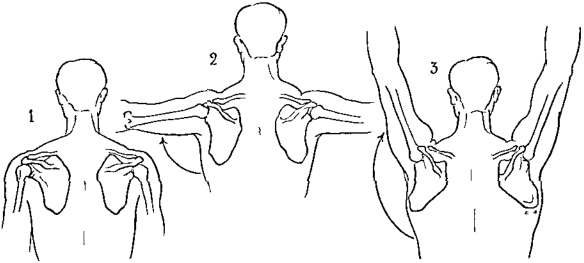


FIG 698 Position of bones of the shoulder girdle in abduction and in elevation

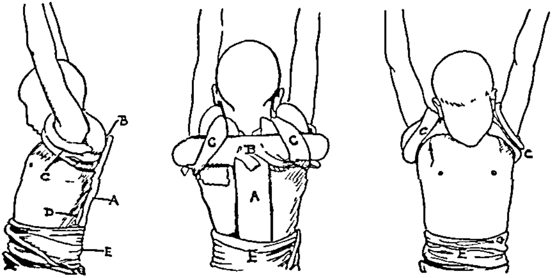


FIG 699 T splint for fracture of clavicle (A) Vertical arm, (B) horizontal arm, (C) padded band binding shoulder to horizontal arm, (D) space between patient's back and vertical arm to be filled by padding (E) bandage holding lower end of vertical arm (Courtesy, Murray, C R Treatment of Injury, New York, Harper & Brothers)

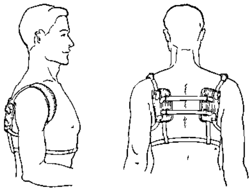


FIG. 700. Simple shoulder brace for fracture of clavicle.

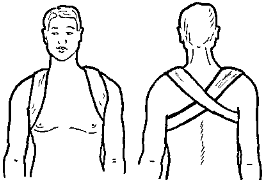


FIG. 701. Figure-of-eight bandage of flannel for fracture of clavicle in children. There should be adequate padding of axillary portion to protect axillary vessels and nerves.

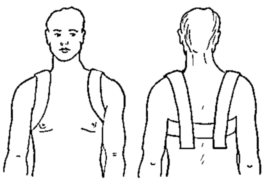


FIG. 702. Plaster double L for fracture of clavicle in older children and slightly built adults. Axillary portion should be well padded, and plaster should be accurately molded and allowed to harden while reduced position is maintained.

(Fig. 700). The principle involved is the same as with the T splint, but the apparatus is less cumbersome and allows the clothing to be worn more easily and more normally. It is not, perhaps, so effective mechanically.

3. In children, a well-padded figure-of-eight cotton or elastic flannel bandage applied from behind with the shoulders held well back will be adequate to carry out the same purpose (Fig 701).

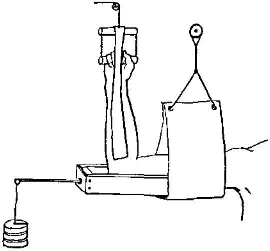


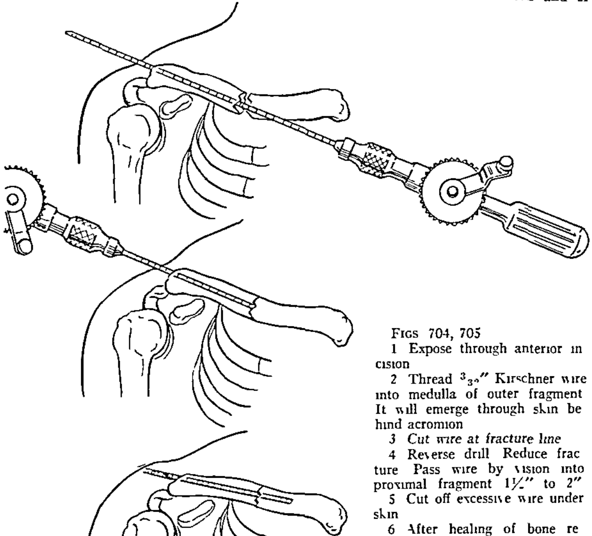
FIG 703. Traction-suspension of upper extremity. Adhesive traction to upper arm and vertical suspension of lower arm.

[In older children, a well-padded double L of plaster of paris can be used (Fig. 702) to good effect. Usually it is not strong enough for adult wear.

While, in general, any device which allows the patient to be up and actively about is more satisfactory than one which immobilizes either the patient or his extremity, in the adult the methods described above will not insure accurate anatomy or minimally visible callus. A visible or palpable callus frequently results If a maximum in the aesthetic result with a minimum of visible or palpable deformity is desired, bed treatment is usually necessary. This requires that the patient lie flat on the back with enough padding under the spine be-

tween the shoulder blades to allow the shoulders to drop back (Stimson) If necessary, the arm on the affected side may be suspended in wide enough abduction to position until good solid bony union is obtained—usually five or six weeks, sometimes longer —Ed]

INTERNAL FIXATION In recent years internal fixation has been advised and ef-



FIGS 704, 705
1 Expose through anterior incision
2 Thread $^{3}{}_{32}$" Kirschner wire into medulla of outer fragment It will emerge through skin behind acromion
3 *Cut wire at fracture line*
4 Reverse drill Reduce fracture Pass wire by vision into proximal fragment 1½" to 2"
5 Cut off excessive wire under skin
6 After healing of bone remove wire under local anesthesia
If wire should migrate it will come out through skin This should always be done as a clean open operation

accurately restore the outer fragment to normal alignment with the inner one, and may be maintained in this position by a few pounds' traction applied through adhesive skin straps to the upper arm (Fig 703) If this arduous treatment is deemed worth while for the sake of the anatomic result

fected by introducing an intramedullary Kirschner wire after reduction, allowing active mobilization thereafter as in the treatment by T splint or shoulder brace methods A sling is used for the first ten days or two weeks as needed When bony union is complete, the wire is removed, no

Fractures through the rhomboid-ligament attachments near the inner end of the clavicle require merely a sling and swathe for a few days, followed by the sling alone with local symptomatic therapy. The rhomboid-ligament attachments prevent displacement Those through the conoid and trapezoid ligaments near the outer end are in the same category. Those beyond the attachments of these latter ligaments, and between them and the acromioclavicular joint, show the same displacement and require the same treatment as the so-called incomplete dislocations of that joint (see below).

Nonunion rarely occurs in fractures of the clavicle When it does happen it usually results from interposition of platysma or, more rarely, subclavius muscle. The treatment is that of nonunion elsewhere, adapted to the clavicle. [See Chapter 22 for treatment of delayed and nonunion.—Ed.]

Sternoclavicular Dislocation. This dislocation as a fresh injury is rare, but it is painful and incapacitating It is easily seen and readily palpated. Dislocation is usually upward Occasionally it is forward or backward. In these latter cases the respiratory distress occasioned by the pressure of clavicle on trachea may be severe, with marked dyspnea and cyanosis. In either displacement the reduction is accomplished by pulling the shoulders back against forward counter-pressure between the shoulder blades as described for fracture of the clavicle, and is maintained by the same methods as described for fracture of the clavicle. The immobilization must be maintained for from six to eight weeks Habitual dislocation of the cases with upward or forward displacement is not uncommon

HABITUAL DISLOCATION. This may occur without an original traumatic lesion, or as a result of it. It may be an annoyance only, or it may be unsightly, and sometimes is painful.

TREATMENT. Treatment is by open reduction The anterior sternoclavicular ligaments are repaired, and the clavicle is held in place by anchoring its inner end to the second rib by a fascial strip After this has been accomplished, satisfactory results will usually follow.

[The intra-articular meniscus is frequently distorted, and must be removed. The repair of the anterior ligaments is at times impossible, and fascial replacements must be used. Chronic arthritis with discomfort or pain may ensue following the repair. Bleeding may be bothersome For these various reasons the procedure here described, as well as other reconstructive operations, may be difficult and disappointing.

Subperiosteal resection of the inner inch or inch and one-half of the clavicle is far more simply done, eliminates the deformity and the threat of later arthritis, and gives excellent function in a short time, since immobilization is needed only until wound healing is assured —Ed]

Dislocation of the outer end of the clavicle is relatively common It usually occurs as a result of a heavy downward blow resulting from a fall on the tip of the shoulder or from a blow by a heavy object The displacement is always of the clavicle upward and backward, and the extent of the displacement is dependent upon the amount of injury to the acromioclavicular and the coracoclavicular ligaments The patient should be examined and x-rayed while standing

Inspection shows the outer end of the clavicle elevated and the tip of the shoulder drooping The dislocation can be reduced by pressing a hand under the elbow upward and backward X-ray examination, standing with the arms hanging, should always include both shoulders on the same plate.

If the clavicle is elevated and the acromion dropped on the affected side, but the distance between the coracoid and the clavicle is the same on the two sides, only the acromioclavicular ligaments are torn and the attachment of clavicle to scapula

by the conoid and trapezoid ligaments is intact If, in addition to the disturbed relation between acromion and clavicle the coracoid and clavicle are more widely separated on the affected side than on the sound side, then the conoid and trapezoid ligaments are torn to a corresponding degree The former is the so called incomplete dislocation, the latter the complete dislocation

Reduction is easy maintenance of reduction, difficult The shoulder must be raised and pulled backward To accomplish this the following methods have been devised

1 A back brace similar to the clavicular splint (see clavicle fracture above)

2 A strap device which holds the end of the clavicle downward by pressure with counter pressure around the point of the elbow, as in the so called Stimson dressing (Fig 706)

3 Surgical operation to restore the acromioclavicular ligaments and the coracoclavicular ligaments in the complete dislocations

Partial Dislocations These are common and often painless even with a severe degree of acromioclavicular displacement Methods 1 and 2 above are adequate for those lesions in which the conoid and trapezoid ligaments are intact The clavicular splint or the Stimson dressing should be kept applied and adjusted for a period of four weeks during which time as much active motion of the shoulder as possible should be practiced At the end of that time the fixation can be dispensed with and gradually increasing active use of the shoulder enforced

Operative Treatment This is reserved for the complete dislocations The outer half of the clavicle is exposed by a curved incision from the tip of the acromion to the junction of the outer and middle third of the clavicle The periosteum is incised and the superior and anterior parts of the bones are exposed The torn meniscus and any ligamentous tabs must be removed from the acromioclavicular articulation The coracoid is exposed from above and passageway beneath it is created subperiosteally

Three holes are drilled (1) Obliquely through the acromion into the acromioclavicular joint, (2) obliquely through the outer end of the clavicle into the joint, and (3) vertically through the clavicle directly above the coracoid process

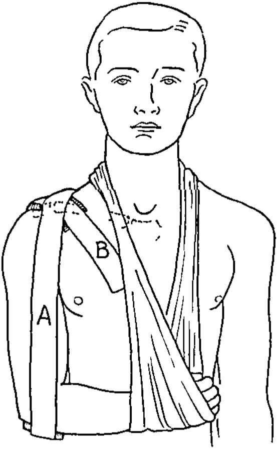


Fig 706 Stimson dressing for incomplete acromioclavicular dislocation Arm A of adhesive strip proceeds over shoulder and lies on scapula in a position comparable to B Arm B proceeds over shoulder and down back of arm in a position comparable to A Felt pads lie between adhesive and olecranon and between adhesive and acromioclavicular joint Dislocation is held reduced by upward pressure on elbow and downward pressure on clavicle while dressing is applied A sling supports hand and wrist

The clavicle is now lashed down into place with fascia lata with one or two strips holding (a) the clavicle to the acromion and (b) the clavicle to the coracoid Tension on the fascial sutures may be relieved by temporary catgut sutures which duplicate them The wound is closed in layers. The arm is held in a sling for three weeks and activity may be resumed in from four to six weeks It is interesting to note that the fascia used to restore the coracoclavicular ligaments almost invariably calcifies (Fig 707)

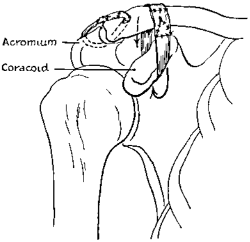


Fig 707. Repair of complete type of acromioclavicular dislocation by fascial bands replacing acromioclavicular and coracoclavicular ligaments A single continuous band may be used (Bunnell) instead of separate bands. Fascia may be used for acromioclavicular ligaments and a portion of peroneus longus tendon for coracoclavicular ligaments.

[There are two other methods in use for the treatment of the complete dislocations:

1. THE TRANSFIXION OF THE ACROMION PROCESS AND THE OUTER THIRD OF THE CLAVICLE BY TWO KIRSCHNER WIRES DRILLED FROM THE FORMER THROUGH THE LATTER (FIG. 708), followed by increasingly active motion, at first with sling support, later without any external support. The wires are removed in six to eight weeks They can be inserted directly through the skin under fluoroscopic control, or after direct exposure of the acromion and the clavicle The procedure is simpler than the fascial suture, requires less exposure, and is very effective. The wires are turned up and cut short at the acromial edge, and the ends lie buried beneath skin. The editor prefers this to fascial suture in fresh cases, but prefers to do it after direct exposure and removal of the meniscus to minimize the chance of subsequent arthritic pain in the joint

2. SUBPERIOSTEAL EXCISION OF THE OUTER ONE TO ONE AND A HALF INCHES OF THE CLAVICLE (GURD). This is the method of choice of a number of men in the fresh cases, and is probably the best procedure in old long-standing ones It is extremely simple, precludes the possibility of late painful

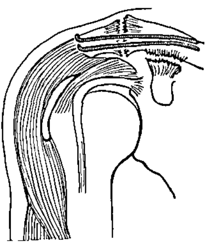


Fig 708 Fixation of complete dislocation at acromioclavicular joint by two stiff Kirschner wires Note turned-up ends of wires to prevent migration, and torn acromioclavicular and coracoclavicular ligaments. Placing the wires requires care, rehearsal on the cadaver, and, if possible, fluoroscopic control if done without open reduction Properly done it is an excellent method of fixation for fresh cases of complete dislocation. If conoid and trapezoid ligaments are intact, it is questionable whether it is justified

arthritic symptoms and can be followed by active use as soon as wound healing is established

If incomplete or repaired complete dislocations are followed by late arthritic pain in the acromioclavicular joint subperiosteal clavicular resection as described above is felt to be the wisest procedure —Ed]

HUMERUS

Fracture of Surgical Neck of Humerus These fractures in general can be classified into two types (1) Those with gross displacement and little or no contact of the fractured surface and (2) those with impacted comminuted ends with bony contact although the head may be rotated or angulated on the shaft

1 WITH GROSS DISPLACEMENT If the x ray shows that there is marked displacement of the fragments gentle manipulation under ether may be attempted after prolonged steady traction in abduction The distal fragment is usually displaced forward and often inward There is no fixed method for effecting reduction Sometimes traction in the opposite direction adduction will accomplish it Frequently both fail in which case open operation should be done

[Before resorting to operation in these cases a wire may be inserted through the olecranon and direct overhead skeletal traction (as described for supracondylar fractures in Chapter 31) may be carried out for a period of 48 or 72 hours A weight of eight to ten pounds should be used During this time the infiltration of soft parts surrounding the fracture site will materially diminish as the result of gravity drainage and muscle spasm will be relieved In this position also the subscapularis and the pectoral are relaxed At the end of the 48 or 72 hour period pentothal or ether anesthesia can be administered as the patient lies in traction and reduction by gentle direct manipulation can be attempted It will frequently succeed obviating the necessity for operation —Ed]

OPERATION The fracture is exposed by an incision running from the tip of the acromion directly downward dividing the deltoid in the direction of its fibers The proximal and distal fragments are exposed and cleared The distal fragment should then be brought to the proximal fragment and levered into place with a skid Internal fixation is rarely necessary The reduction is usually maintained in the position of ab

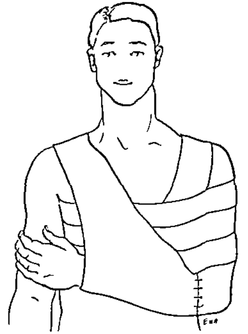


FIG 709 Sling and circular bandage or swathe Sweat pad should be placed in axilla

duction and external rotation in a plaster splint or any so called airplane splint The splint may be removed and the arm brought down to the side after three weeks If a plaster splint is not well tolerated external rotation and abduction can be maintained with the patient in bed by adhesive plaster traction applied to the upper arm and balanced suspension applied to the forearm with the elbow at a right angle (Fig 703) Active motion may be begun after four weeks Good anatomic and functional results usually follow

2 WITH IMPACTED COMMINUTED ENDS WITH BONY CONTACT Reduction of such

a fracture is unnecessary. Simple fixation using a sling, swathe, and axillary sweat pads is all that is needed (Fig. 709). Active motion of the hand, wrist, and elbow may be begun when the patient is still in the sling. At the end of a week, or earlier, pendulum exercises of the shoulder may be started. These may be done with the patient leaning forward holding a two-pound weight and swinging it six or eight times to 15 or 20°, several times a day The range and arc of the pendulum are increased daily, until, at the end of three weeks, 90° flexion has been obtained (Fig. 710). A sling is the only necessary dressing After a month no fixation is necessary, but the pendulum exercise should be continued until solid bony union is demonstrated by x-ray. In such cases, excellent anatomic results will be obtained in 75 per cent and good economical results in 85 per cent of the cases Because most of these cases occur in elderly patients, this type of treatment is strongly recommended. Prolonged fixation is unnecessary and early function gives best results.

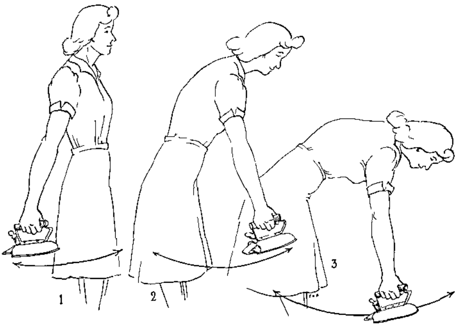


FIG. 710. Pendulum exercises. Range practiced by weeks—1, 2, and 3. In the second and third weeks swinging across front of body is also practiced.

Fractures of Anatomic Neck of Humerus. By this is meant fractures above the tuberosities in which the head fragment has no, or practically no, soft-part attachments The tuberosities may be split off as separate fragments in some of these cases Where there is little or moderate separation of the head fragment, the case should be treated as a similar fracture of the surgical neck When, however, the head is completely or almost completely displaced from the shaft and tuberosities there is considerable difference of opinion as to the best course to follow. Some men believe that reduction—closed if possible, open if necessary—should be done as advised for the surgical-neck cases, and followed by the same régime. Because of the paucity of soft-part attachments, however, late degenerative changes are apt to occur in the head even after union takes place, resulting in mushrooming of the head and a stiff and painful joint. The situation is comparable to that of the subcapital neck of the femur fractures of the coxa-vara type For this reason some men are inclined to resort to

open exposure in these cases as a first resort to remove the head and to place the upper end of the shaft in the glenoid In younger people operative arthrodesis of the shoulder after removal of the head has been advised This may be considered rather radical as a primary procedure

At any rate the prognosis in these cases should be very guarded even though a satisfactory reduction is accomplished

If open reduction is necessary replacement of a head devoid of soft part attachments or practically so should be done only with a thorough realization of what may ensue

Fractures of Greater Tuberosity Fractures of the greater tuberosity alone are uncommon They usually occur in patients in about the fifth decade The complaint is usually pain on the tip of the shoulder with tenderness and soreness Sometimes several x rays must be taken before the lesion can be shown Pendulum exercises and early active motion may be begun as soon as the acute tenderness has subsided Temporary fixation until that time in the position of 45° flexion 45° abduction and 45° rotation often is the most comfortable Later a sling with a large axillary pad is useful between periods of active motion

[Occasionally the greater tuberosity is pulled free from its periosteal attachments and is drawn up and back under the acromion by the action of the supra and infraspinatus When this occurs which is not often operative reduction and fixation are indicated —Ed]

Epiphyseal Separation This frequently occurs in patients between 12 and 17 years of age Usually it is a result of a fall upon the extended hand The diagnosis is often impossible without x ray films as the symptoms presented are the same as those of a fracture of the surgical neck Usually it is accompanied by a splinter fracture of the outer cortex

Treatment If there is complete or almost complete displacement and if the injury is less than 24 hours old an anesthetic may be given and an effort made with extreme gentleness to bring the shaft into the epiphyseal cup If this is not easily accomplished the attempt should be abandoned If the injury is more than 24 hours old or if the above attempt has failed and complete displacement exists overhead traction by a wire through the olecranon (as described for supracondylar fractures in Chapter 31) may be instituted Manipulation in late cases is futile and dangerous

If there is not great displacement no manipulation should be attempted and the humerus should be immobilized in a plaster shoulder cap for about one week Surgical operation in these cases is neither necessary nor desirable Experience has shown that even if there is a considerable degree of displacement a good result may be expected if there has been no injury to the epiphyseal cartilaginous plate Manipulation and open reduction are apt to produce damage to the plate if the trauma of the injury has not done so

SCAPULA

Fractures Even though it is exposed above and behind fractures of the scapula are relatively rare Fractures of the blade occasionally occur but do not require treatment apart from local physical therapy and the encouragement of active motion with or without the use of balanced suspension Fractures of the spine even with gross displacement give clinically satisfactory results under the same routine Fractures of the coracoid are rare except when associated with other extensive fractures of the shoulder Fractures of the neck and of the glenoid usually due to heavy objects falling upon the shoulder and various combinations of fractures occur Usually reduction of any of these fractures is impossible and functional activity is the basis of treatment Fractures of the glenoid are by far the most serious and are treated by traction in abduction with the patient in bed (Fig 703)

Occasionally, in depressed comminuted fractures of the neck, operative reduction is necessary to restore the anatomic position

The end-results are usually satisfactory and the average length of disability is about three months.

Dislocation of Shoulder. The shoulder joint is well protected and strong above, in front, and in back. The muscles and tendons are powerful Below, however, the capsule is weak and ill-guarded The capsule is necessarily loose to allow the functional range necessary in the joint.

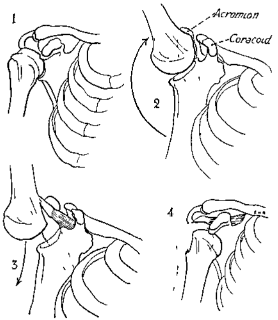


FIG 711. Mechanism of shoulder dislocation and associated injuries· (1) Shoulder at rest; (2) arm above head; (3) greater tuberosity of humerus impinges on acromion process; (4) Head leaves glenoid and (a) greater tuberosity may remain intact and spinati muscles be put on the stretch, (b) tuberosity may be wedged off, (c) spinati may rupture.

As the result of a fall the arm extends to parry and protect, and the whole weight of the body falls upon the arm while the muscles are in contraction. The humerus is brought into forced hyperextension and then it strikes the acromion, which is firm and nonyielding. As a result of this fulcrum action the lower portion of the capsule is torn and the head of the humerus forces itself through As the arm is returned to the side the head usually is displaced anteriorly, with the torn capsule firmly caught about the surgical neck.

In addition, sometimes, the greater tuberosity is torn off like a trap door. Sometimes the supraspinatus tendon may be ruptured. It is difficult for the author to understand how there can be a dislocation of the head without injury to the tendon of the supraspinatus or without fracture of the greater tuberosity. Tendon injury must be suspected if the x-rays are negative for fracture (Fig. 711)

Examination should check motor and sensory neurologic changes referable to the brachial plexus and the axillary nerve.

In certain anterior dislocations the anteroposterior x-rays give the appearance that the head is in the glenoid. In these cases careful physical examination shows the true position of the head and palpation of the shoulder reveals the true position of the head with the empty glenoid behind it

TREATMENT Efforts at reduction should be instituted promptly. An anesthesia sufficient to produce complete muscular relaxation is necessary. The arm is then brought into right-angle abduction, and straight gentle traction is applied until all the muscle resistance is overcome (A folded sheet about the body of the patient furnishes counter-traction). This may require from five to ten minutes. After this has been done, the head of the humerus may then be gently reduced through the rent in the capsule by direct pressure. In fresh dislocations this can practically always be done and should be attempted in ancient cases even after two or three months. In these cases it may be necessary to use steady traction upon the arm for as much as 30 minutes. Following this prolonged traction the head can often be slipped back

into the joint through the capsular rent After the shoulder is reduced it should be kept in a sling for two or three weeks then active stooping exercises should be instituted (Fig 710)

The Kocher method has been extensively used in the past, but the author has not used it for several years It is his belief that the simple traction method accomplishes reduction with less trauma and less danger to the shaft of the humerus

THE KOCHER METHOD With the arm at the side, the elbow flexed to 90°, and the forearm supinated, after the period of traction described above and with that traction maintained, the humerus is slowly rotated outward to the limit attainable without the use of undue force Maintaining this outward rotation and the traction the elbow is slowly carried forward and inward across the chest wall as far as it will go Steadily maintaining the traction the humerus is then slowly rotated inward aiming the hand at the opposite shoulder The reduction will occur during the inward rotation, and the ability to place the hand on the opposite shoulder without the use of undue force is practical proof of the reduction *At no time should undue violence be used to force a maneuver, and at no time should one of these steps be performed suddenly* A Kocher procedure so performed can do no damage

In the late cases, or in the very exceptional early case where all these measures fail, overhead traction by a pin through the olecranon for 24 or 48 hours (see Supracondylar Fractures in Chapter 31), followed by direct manipulation in traction under ether or pentothal anesthesia may succeed Only after these conservative attempts fail should open reduction be resorted to —Ed]

Dr E A Codman believes that after reduction the patient should be allowed to come out of the anesthetic and then urged to move the arm freely before bandaging He says

All motions may be safely performed except abduction in external rotation and even this may be done with due care and using extension at the same time If we find paralysis of any of the muscle areas undue axillary swelling, gritting sensation in the joint or a tendency of the joint to slip out of place the patient should be at once hospitalized and consultation obtained

COMPLICATIONS Often associated with dislocation there is a fracture of the greater tuberosity As the head of the humerus is forced out of the glenoid, the shaft of the humerus impinges upon the acromion and the greater tuberosity is torn from its bed I have often suspected that by the same procedure the supraspinatus tendon may be torn instead of its bony attachment This tendon is short and strong and surely must be stretched or torn during the relatively long journey that the head makes during dislocation If there is no fracture tear of the supraspinatus tendon requiring operative repair must be kept in mind, and excluded as function is regained

There may also be fracture and avulsion of the lesser tuberosity with the attached subscapularis tendon If the separation is marked, operative replacement should be considered with fixation by wiring This is not a common complication and when it does occur the separation is usually minimal Under these circumstances the complicating lesion is merely an indication for the necessity of early mobilization to prevent contracture and shortening of the subscapularis with consequent limitation of abduction and external rotation

Fracture of the surgical neck associated with dislocation rarely occurs This presents a serious problem to the surgeon Reduction should not be delayed After prolonged gentle traction in abduction an effort should be made to replace the head by manipulation and replacement with the fingers Great power or force is neither necessary nor wise Failing all of these, surgical

operation should be done, the fracture-dislocation exposed, and reduction accomplished. After reduction, the treatment is the same as that for a fracture of the surgical neck Only in fractures of the anatomic neck is it necessary to remove the head of the humerus When this is done the smoothed-off end of the shaft is placed in the glenoid, and active function is started early.

The initial examination of every dislocated shoulder should call for examination to determine the possibility of damage to the axillary nerve In the acutely traumatized shoulder, tests of deltoid function are valueless because of pain limitations The sensory distribution of the axillary nerve to the skin over the deltoid is, however, an excellent criterion. Marked hypesthesia or complete anesthesia in this region indicates relatively severe damage to the axillary nerve. Actual rupture of the nerve practically never occurs, but severe contusion and stretching lead to the sensory changes plus deltoid weakness.

When such sensory findings are present at the time of the original examination or following reduction, the postreduction therapy should employ bed rest, with suspension of the arm in about 50 to 60° of abduction (Fig. 703), plus local physical therapy and active motion up to, but not beyond, 80° of abduction and 60° of forward elevation If complete anesthesia and complete deltoid paralysis are present, which is unusual, muscle stimulation by the sinusoidal current or by the use of a Smart or Bristow coil may be substituted for the actual motion.

An alternative to the bed-rest therapy with active motion is the use of an airplane type of splint in about 60 to 70° of abduction with active attempts at contraction of the deltoid in the splint until the skin sensation has returned, indicating nerve recovery. The purposes of both the bed-rest treatment and the abduction-splint treatment are to keep the weakened or paralyzed deltoid from being kept under tension and stretched while it is weak or paralyzed

The recognition of severe axillary-nerve injury, with adequate attention (as described above) given to it, will materially diminish the convalescence time in these cases When the hypesthesia is questionable or mild the measures described above are not necessary.

After-treatment. A simple sling to keep the arm at the side is the only necessary treatment. Pendulum exercises should be begun immediately and carried out with increasing range of motion until full flexion and extension have been accomplished. Specific efforts to obtain abduction of the arm are not necessary If there has been fracture to the greater tuberosity, ability to abduct the arm may be delayed and full motion may not be obtained for a long time If there is no fracture of the greater tuberosity, tearing of the supraspinatus tendon must be considered as stated above

Old Dislocations. Occasional cases present themselves that have remained unreduced for months. There are several procedures to follow:

1. Try to reduce it by one of the closed methods under anesthesia This, if carefully done, is often successful

2. Excise the head of the humerus This usually gives a painless but not particularly useful joint.

3 *Do nothing* if there are no nerve injuries and the patient has a painless joint This is frequently advisable

After all of these procedures, the muscles of the shoulder girdle must be exercised daily.

4. Open Reduction In the old unreduced dislocation this is a difficult and arduous procedure, and since the humeral head and upper shaft are atrophic and soft, manipulation and handling of the bone must be carried out with caution. The vessels and nerves may also be enveloped and dis-

torted by scar tissue and adhesions and must be identified in order to guard against injury to them

The fresh case, uncomplicated by fracture which requires open reduction is very rare, indeed, and the procedure is, of course, very much simpler than in the old and neglected case In these older cases reduction should be done only if the head and glenoid, on inspection are in good condition, and if the head can be reduced without too complete stripping of the soft parts to the upper humerus When the latter procedure is necessary in order to accomplish reduction, degenerative changes such as follow anatomic neck fractures are common after operation resulting in pain and stiffness in the joint Resection of the head or arthrodesis of the joint in the position leading to the most satisfactory function is to be preferred in these cases This is also true if the head and glenoid show marked degenerative change when exposed even though no undue stripping has been necessary

Technic in Fresh Cases Which Have Resisted Conservative Measures Adequate exposure is obtained by an incision running along the outer third of the clavicle at its inferior border to the anterior outer edge of the acromion and then directly downward over the deltoid for about three inches The interval between the deltoid and the pectoralis major is defined the median cephalic vein being ligated high and low and excised between the ligatures The deltoid is sectioned close to the clavicle from its anterior edge, and from the front and outer edges of the acromion and the deltoid is reflected downward and outward to expose the coracoid region and the whole anterior aspect of the shoulder It is preferable in the opinion of some to reflect the deltoid attachment together with the anterior periosteum instead of severing the muscle close to its attachment, on the grounds that it leads to greater ease and security in reattachment at the close of the operation (Fig 712) The vessels and nerves to the deltoid accompany the reflected muscle and are subjected to a minimal risk of damage The exposure obtained is excellent

After identification of the various structures the capsule is opened longitudinally and the head is reduced by external rotation and adduction of the upper arm aided by direct pressure on the head with the aid if necessary, of the shoehorn action of a large curved elevator or skid Any rent in the anterior inferior portion of the capsule is repaired by overlap The musculotendinous cuff inserting into the greater tuberosity is carefully inspected for tears in any of its components and if found these are repaired [See Chapter 42 for technic of repair —Ed]

Avulsion of the greater or lesser tuberosity is repaired by pegging nailing or wiring in the proper position The stripping of the capsule from the anterior and inferior aspects of the scapular neck with avulsion of the glenoid ligament (described by Bankart) one of the causes of habitual dislocation is looked for and if found is repaired by attaching the stripped capsule to the bone by sutures passing through drill holes close to the glenoid rim The biceps tendon is inspected and if avulsed from its groove is replaced and covered by a reflected flap of periosteum acting as a new roof for the groove The longitudinal incision in the capsule is closed and the deltoid reattached

The after treatment is that of a fresh dislocation reduced by conservative measures

Technic in Old Unreduced Dislocation The approach is the same as that described in the fresh case By careful blunt and sharp dissection the capsule of the joint the coracohumeral ligament, and the head covered by dense fibrous tissue are defined The capsule of the joint is incised longitudinally in line with the anterior outer edge of the acromion Through the opening in the capsule any fibrous tissue filling the glenoid is removed The coracohumeral liga

ment is sectioned at its coracoid end. If inspection of the head and glenoid shows marked degenerative change reduction is not carried out, but resection of the head, placing the smoothed-off end of shaft in the glenoid, or arthrodesis [see Chapters 7, 14, and 15] is carried out.

If the humeral head and the glenoid are in good condition, the head and neck are freed from capsular and scar-tissue adhesions and attachments far enough down to allow placing the head in the glenoid by the use of carefully applied and moderate force If moderate force will not accomplish this without such extensive stripping as to endanger the blood supply to the head and neck, the humerus can be rolled out and the subscapularis tendon sectioned, and then, if necessary, rolled in for section of the pectoralis major tendon If section of these tendons with moderate stripping of capsular attachments will not allow of reduction with very moderate force, resection of the head with or without arthrodesis of the shaft to the glenoid is preferable to dangerously extensive stripping.

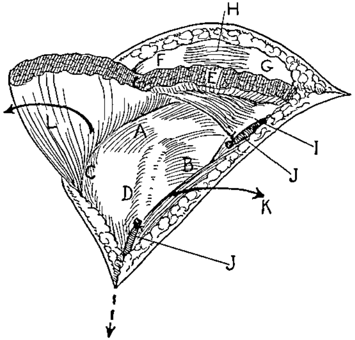


Fig. 712. Incision for exposure of shoulder. [See also repair of supraspinatus tears in Chapter 42] (A) Supraspinatus portion of cuff. (B) Subscapularis portion (C) Infraspinatus portion. (D) Biceps tendon sheathed in its groove. (E) Cut edge of deltoid attachment to (F) acromion process and (G) clavicle. (H) Acromioclavicular joint (I) Coracoid process with coraco-acromial ligament and (below) attachments of short head of biceps, pectoralis minor, and coracobrachialis. (J) Cut and ligated ends of median cephalic vein. (K) Direction of retraction of pectoralis major. (L) Direction of retraction of cut deltoid. Subdeltoid bursa area is indicated by light area overlying supraspinatus. Extension can be secured in direction of dotted line below, or by further backward section of deltoid or by section of outer part of pectoralis major attachment to clavicle and of coraco-acromial ligament.

Following reduction it is rarely possible even in abduction to close the capsule A Nicola procedure (see below under Recurrent Dislocation) may be done to insure retention of reduction Postoperatively immobilization in a position midway between abduction and forward flexion and in about 45° of each with the upper arm rotated to 45° should be maintained by any suitable splint for three to four weeks to be followed successively by pendulum exercises and aided and resisted active exercise against gravity

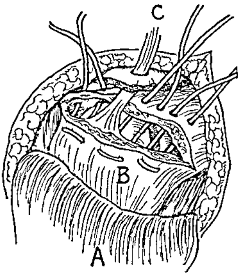


FIG 713 Cubbins operation Coracohumeral ligament is first dissected free and detached from coracoid It is utilized as a stabilizing checkrein through acromion after reduction has been accomplished through a wide transverse incision in capsule through which all capsular structures are stripped from humerus as far down as possible Closure *of capsular opening is then accomplished* as far as possible as shown (A) Reflected deltoid (B) capsular incision (C) coracohumeral ligament through acromion

Cubbins has modified this procedure by passing the coracohumeral ligament dissected free from its coracoid end up to its humeral attachment through a drill hole in the acromion process from below upward and suturing it to the superior surface of this bone to create a suspensory stabilizing ligament the superior half of the capsular opening (corresponding to the musculotendinous cuff) being sutured to the greater tuberosity via drill holes through the bone (Fig 713)

Unless the head and the glenoid are in good condition and unless reduction can be accomplished with quite moderate stripping and little or no violence the open reduction of the late case carries a rather discouraging prognosis Considerable stiffness and pain are commonly the residua after operation

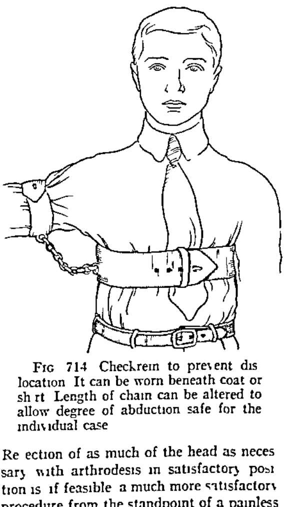


FIG 714 Checkrein to prevent dislocation It can be worn beneath coat or shirt Length of chain can be altered to allow degree of abduction safe for the individual case

Resection of as much of the head as necessary with arthrodesis in satisfactory position is if feasible a much more satisfactory procedure from the standpoint of a painless and reasonable range of useful motion In the relatively recent case the attempt at open reduction with an added Nicola or the Cubbins modification utilizing the

coraco-acromial ligament and reattaching the musculotendinous cuff, may be well worth while.

When brachial-plexus symptoms are present in these cases it is distinctly worth while to define the nerves clearly by meticulous sharp dissection, and, if their continuity is not severed, to inject normal saline into the nerve through a fine-gauge needle introduced within the sheath If the nerve or cord distends reasonably freely, the prognosis for recovery (in part at least) may be good, and the neurolysis accomplished by hydraulic distention within the nerve sheath is not accompanied by bleeding with the threat of subsequent fibrosis. This has been found of definite benefit in a number of cases, and dramatic in its effectiveness in a few.

Recurrent Dislocation of Shoulder Joint. *This is a common lesion. Prolonged* immobilization does not cure after the tendency to dislocation becomes fixed Dislocation can be prevented by the wearing of a restraining check-rein which prevents abduction or forward elevation beyond 80° (Fig. 714). Some method of radical cure should be attempted, however, if the dislocations become frequent and occur easily

Many approaches to the cure of this condition have been used Reefing of the capsule anteriorly or inferiorly—in the latter instance through an axillary incision with the shoulder abducted (T. Turner Thomas) —has been generally discarded because of a high rate of recurrence. The providing of a muscular sling under the head and neck by advancement of the subscapularis or by

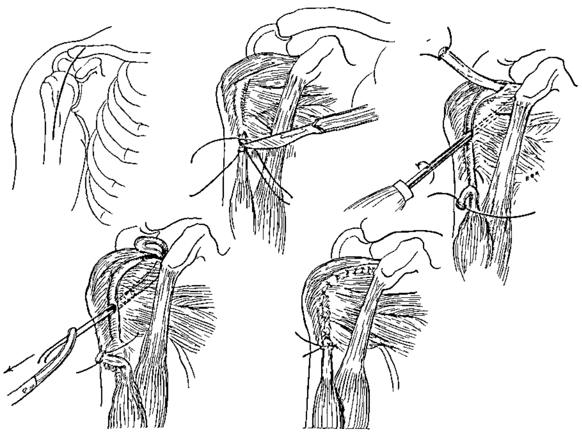


FIG 715 Nicola operation for habitual dislocation of shoulder.

utilizing a slip of deltoid (Clermont operation) has suffered a similar fate Bone block operations have been and are being used Suspension of the humeral head by means of the biceps tendon (Nicola) or by fascia or tendon suture from the greater tuberosity to the acromion (Henderson) are also in use as well as the Bankart procedure

NICOLA'S OPERATION The operation performed by Nicola (Fig 715) seems the simplest and most successful The head of the humerus is exposed through a two and a half or three-inch incision beginning at the posterior tip of the acromion and splitting the deltoid fibers avoiding the circumflex nerve in the lower end of the wound The subacromial bursa is opened Under the floor of the bursa the upper part of the shaft of the humerus and the joint capsule can be seen The long tendon of the biceps is easily identified and is freed from the bicipital groove The shoulder joint capsule is opened in the line of the bicipital groove and the entire tendon of the long head of the biceps is visualized The tendon is cut at the lower end of the bicipital groove after traction sutures have been placed proximal and distal to the point of section If this is not done the distal portion of the tendon may retract down the arm This gives a proximal section of tendon about three and a half inches long attached to the glenoid

A tunnel is made with a quarter inch hand gouge beginning at the lower end of the bicipital groove and passing beneath it to emerge on the articular surface of the humerus about 30° inside the vertical plane well on to articular surface The incision in the roof of the capsule is extended so that the inner end of this tunnel can be exposed This is facilitated by pulling the joint outward and letting air into the joint The proximal end of the biceps tendon is then pulled through the tunnel from above by the silk traction suture until it emerges at the lower end of the bicipital groove At this point the two ends of the tendon are

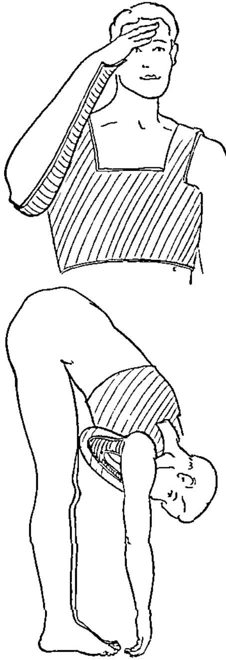


FIG 716 Plaster-of-paris shoulder splint best made a few days before operation and applied immediately after operation Position is one of 45° flexion, 45° abduction and 45° external rotation If a post is incorporated between chest portion and wrist portion upper half of arm casing may be lifted and arm removed for carrying out pendulum exercises

firmly sutured with silk. The capsule is closed, and the muscles, fascia, and skin are closed with silk sutures.

It is often more comfortable for the patient if the arm is put in a light plaster-of-paris splint with the arm held at 45° flexion and 45° abduction. Such a splint, if prepared before, can easily be slipped on following operation (Fig. 716). This procedure has proved to be very successful and gives permanent relief in a high percentage of cases. The arm must be kept immobile for about a month and then pendulum exercises and active use of the shoulder may be begun.

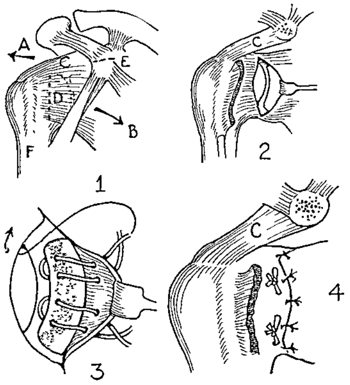


FIG. 717. Bankart operation for habitual dislocation of shoulder (1) (A) indicates deltoid reflection or retraction; *(B) indicates pectoralis major retraction*, (C) is supraspinatus, (D) is subscapularis with dotted line to indicate section, (E) is coracoid with attachments of pectoralis minor, coracobrachialis, short head of biceps, and coraco-acromial ligament. Coracoid is sectioned as indicated, and retracted downward, subscapularis is retracted inward. (F) is biceps tendon. (2) Coracoid and subscapularis retracted, transverse incision through capsule a short distance from glenoid edge, inner portion including torn or avulsed glenoid ligament. (3) Anterior edge of glenoid shaved off to cancellous raw bone, sutures placed through inner flap of capsule and drill holes in bone to pass through outer flap of capsule as indicated (4) Completed overlap suture of *capsule. Coracoid and its attachments are then replaced* during closure.

In addition to suturing the two ends of the tendon together it is wise to roughen the under-surface of the tendon and the sur-

face of the bicipital groove and to attach both sections of the tendon to the sides of the groove by suture to the remains of the *fascial roof or through drill holes through* the sides of the groove

With increasing interest in and observations on shoulder joint pathology it is being realized that the etiologic factors resulting in habitual dislocation are varied For that reason full and adequate exploration of the joint in every case is being more and more favored An incision which will allow full visualization is therefore advocated This is either the one described previously in this chapter for open reduction of the unreduced dislocation or the incision described for repair of musculotendinous cuff tears in Chapter 42

In some of the cases extensive tears of the musculotendinous cuff with retraction will be found and their adequate repair (see Chapter 42) will result in a restoration of superior support for the humeral head and a cure of the habitual dislocation In others the stripping up of the capsule from the anterior and inferior aspect of the scapular neck and avulsion of the glenoid ligament described by Bankart is found This is often associated with a beveling off of the anterior inferior margin of the glenoid fossa A Bankart repair is all that is needed in those cases where these are the findings

BANKART'S OPERATION The coracoid process is sectioned from above downward by an osteotome about 1.5 to 2 cm from its tip and retracted downward with its attachments (coracobrachialis pectoralis minor and short head of biceps) The shoulder is outwardly rotated and the subscapularis is sectioned close to its insertion exposing the underlying anterior joint capsule and glenoid The capsule is incised transversely close to the glenoid margin anteriorly and the portion remaining attached to the scapula if not already stripped up is stripped from the front of the scapular neck adjacent to the glenoid and a thin layer of the anterior bone surface including the edge of the glenoid is removed If the anterior edge of the glenoid has seemed beveled off *a thin osteotome can be driven into the* bone from before backward for a distance of 1 cm or more from the edge of the glenoid and the anterior edge of the glenoid

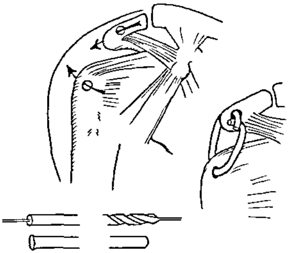


FIG 718 Henderson operation Stabilization is accomplished by establishing a checkrein joining greater tuberosity and acromion Fascia in the form of a rolled strip or a portion of peroneus longus tendon is used Approach may be by deltoid reflection or by a curved incision from in front of greater tuberosity up over tip of acromion and down behind greater tuberosity splitting deltoid in front and behind A cannulated drill over a Kirschner wire is used to make fore and aft hole through acromion A metal cannula serves to facilitate passage of a section of peroneus longus tendon or a rolled fascial strip through drill holes

can be wedged forward and outward to a normal level

Four drill holes are then made from the edge of the denuded glenoid margin to emerge on the edge of the articular surface adjacent to it Through these drill holes by mattress sutures the distal edge of the incision in the capsule is anchored down to the denuded anterior edge of the glenoid (Fig 717) The detached coracoid with its attached muscles is sutured to its base but

projecting directly downward, thus lowering the level of the muscular attachments and the downward extent of the coracoid, which together constitute a muscle-tendon and bony buttress in front of the joint. A sling and swathe is used for about four weeks, after which active motion is progressively re-established.

HENDERSON'S SUSPENSION OPERATION This operation provides a suspension check ligament of fascia or of tendon (a longitudinal half of the peroneus longus is commonly used), which passes through transverse drill holes in the greater tuberosity and in the acromion process (Fig. 718). Postoperative immobilization by sling and swathe is used for ten days, followed by progressive active mobilization aided by physical therapy. Excellent results with a low rate of recurrence are reported.

KELLOGG SPEED'S PEG OR SHELF OPERATION. This aims at establishing an anterior bone block to prevent dislocation. The incision extends from the coracoid process just below the clavicle directly downward for four inches. The pectoralis major is sectioned close to its insertion into the outer lip of the bicipital groove. The axillary contents are retracted upward, exposing the anterior face of the glenoid and the attached capsule. Just outside the edge of the capsular attachment a half-inch-wide heavy osteotome is directed obliquely backward and mesially, and is driven into the scapular neck for a distance of one inch A tibial cortical graft a half inch wide and one and three-quarter inches long is driven tightly into the cleft made by the osteotome. This leaves three-quarters of an inch of graft projecting obliquely forward in front of the joint to provide a bony buttress to prevent dislocation. The pectoralis is then repaired. Sling immobilization is used until bony union of the graft has taken place.—Ed.]

Injuries to Muscles and Tendons. There are certain tendons in and about the shoulder joint that are particularly susceptible to injury and deserve mention at this time.

Rupture of Supraspinatus Tendon. Ninety per cent of the ruptures of the supraspinatus occur in men, who are, for the most part, heavy laborers and almost always over 45 years of age. They give a history of an injury due to a fall or to heavy lifting, sometimes with a slip or a sudden jerk. There is no history of a previous injury or of a previously painful shoulder. Let us here quote Doctor Codman's criteria:

> Certain conditions, symptoms, and signs which indicate complete rupture of the supraspinatus tendon and which should be present within 24 hours after the accident.
>
> 1. Occupation—laborer.
> 2. Age—over 40.
> 3. No symptoms in shoulder prior to accident.
> 4. Adequate injury—usually a fall
> 5. Immediate sharp, brief pain
> 6. Severe pain on following night
> 7. Loss of power in elevation of arm.
> 8. Negative x-ray.
> 9. Little, if any, restriction when stooping.
> 10. Faulty scapulohumeral rhythm
> 11. A tender point,
> 12. a sulcus, and
> 13. an eminence
> 14. at the insertion of the supraspinatus,
> 15. which cause a jog,
> 16. a wince and
> 17. soft crepitus as the tuberosity
> 18. disappears under the acromion when the arm is elevated, and usually also, as it reappears during descent of the arm

Usually the patients do not present themselves until long after the injury, and it is not until then that diagnosis can be made Unfortunately, the difficulty of repair increases with the length of time following injury.

PHYSICAL EXAMINATION. The patient must be stripped to the waist. Inspection of the shoulders comparing one with the other will show presence of atrophy. In rupture

of the supraspinatus, atrophy of the spinati is a constant sign

With the hands hanging loosely at the side, the patient is asked to bend forward, letting the arms hang There is little or no muscular power used in this maneuver, and the patient can usually do it without pain As he bends forward the humerus falls into complete flexion until it is in a straight line with the spine of the scapula As the patient assumes an erect position the arm falls freely to the side This procedure rules out adhesions within the bursa or shoulder joint

The patient then faces away from the examiner He is instructed to slowly raise both arms away from the body with the elbow stiff If the arm can go the entire arc of normal shoulder motion without a hitch there can be no serious injury to the tendons If, however, on trying to abduct the arm the patient raises the scapula first and then the humerus locks as it comes under the acromion, the scapular humeral rhythm is disturbed The arms are then brought high over the head by flexion with the help of the examiner and then the patient is asked to lower the arms He keeps the scapula and humerus fixed until he arrives at the right angle position, and then the arms drop quickly to the side, usually with pain

The two above procedures are of great value in the diagnosis of supraspinatus tendon tear

Further physical examination may be as follows

PALPATION The examiner stands behind the patient and grasps the elbow of the affected side The humerus is then brought back into complete extension from behind The index finger is placed just outside the tip of the acromion and pressed downward while the arm is moved a bit forward This point of pressure corresponds to the insertion of the supraspinatus tendon Usually even in rather ancient cases this point is extremely tender It represents the gap between the ruptured tendon and the greater tuberosity As the arm is brought forward the finger falls into and then out of a sulcus at this point, causing a jog, a wince, and soft crepitus as the tuberosity disappears under the acromion during elevation of the arm, and usually it reappears during descent of the arm (Fig 719)

The great majority of these symptoms are present immediately following injury, but cannot be promptly interpreted until several days thereafter I have never been able to make the diagnosis within ten days At that time at operation it is found that there is a hemorrhage into the tendon and the repair is accomplished with considerable ease

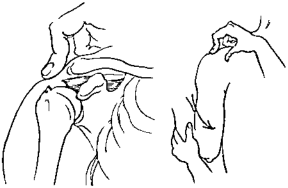


FIG 719 Examination for rupture of musculotendinous cuff of shoulder It is necessary to press hard with index finger

Usually the pain following the injury is quite severe, but it quiets down after a few days and then is bad only at night, and the patient tosses about in fitful sleep

In incomplete rupture the history and the physical examination are much the same There is lack of humeroscapular rhythm, inability to raise the arm, lack of restriction to motion on stooping, and a tender sensitive point This constitutes a painful, serious, and disabling injury

Untreated cases with partial rupture often deposit calcium in the tendon as a part of an effort to repair

TREATMENT The treatment of rupture of the supraspinatus muscle is surgical repair

The lesion is so disabling and so incapacitating that exploration is justified even when the lesion is only suspected. If the tendon is not ruptured, the exploration is only into the subacromion bursa and is distinctly a minor procedure. [For further discussion of this lesion and its repair see Chapter 42.—Ed.]

Rupture of Biceps Tendon. The cause of rupture of the long head of the biceps is a sudden muscle contraction almost always due to indirect force. Usually the rupture is high up at or above the upper musculotendinous junction.

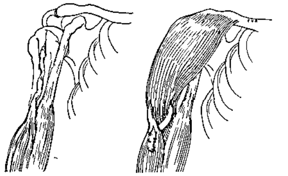


Fig. 720. Operation for repair of long head of biceps (Cotton) Torn tendon is anchored about insertion of deltoid muscle.

Diagnosis. Inspection of the arm in abduction, elbow in flexion. A sulcus is palpated between the insertion of the deltoid and the biceps. This and the tumor of the biceps are increased by efforts to flex the forearm against resistance.

Treatment. The author has often seen elderly workmen doing their full duties with a complete rupture of the long head of the biceps with a characteristic deformity of the biceps muscle. The injury had gone unrecognized for years. The author believes surgical repair is the best treatment.

Cotton's Operation (Fig. 720). Cotton's operation can be done under local anesthesia. The ruptured tendon of the long head of the biceps is found and is anchored by suturing it about the insertion of the deltoid muscle. This tenses the muscle upward and outward, and gives it a firm anchor. The after-treatment is simple and the patient is able within a month to return to his normal work.

Gilcreest's Operation. In this operation the ruptured long head is sutured to the coracoid process along with the short head, or is inserted into the short head as high as possible. The after-treatment of these would be the same as Cotton's operation. To the author, Cotton's operation seems simpler and the results are satisfactory. [See Chapter 42 for further discussion of this lesion.—Ed.]

Injuries to Brachial Plexus.

Causes:

1. Blows or falls upon shoulder.
2. Prolonged traction accompanying dislocations or reduction of dislocation. Birth paralysis.
3. Pressure:
   a. Crutch paralysis or tourniquet paralysis.
   b. Unreduced dislocation of shoulder.
4. Direct injuries:
   a. Cuts or wounds.
   b. Fractures or dislocations causing direct injuries.

There are other injuries due to pressure which are not uncommon All of them soon get well when the pressure is removed.

In the more severe types, as when there is actual lysis of the plexus from a missile, a cut, a violent blow which depresses the shoulder, or a gunshot or stab wound, immediate operation is advisable and necessary, but it should not be undertaken except by one trained in this type of surgery and with a full and thorough knowledge of the anatomy (Fig. 721). Often parts of the neurovascular bundles are injured and the surgeon must be equipped to repair the artery or vein as well as the cords of the brachial plexus. It is in the cases where there is evidence of pressure about the brachial plexus that care in expert hands

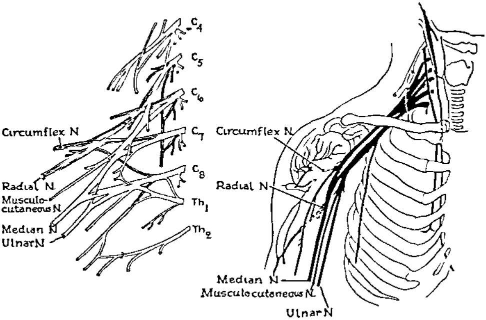


FIG 721 Diagram of brachial plexus (after the Army Manual)

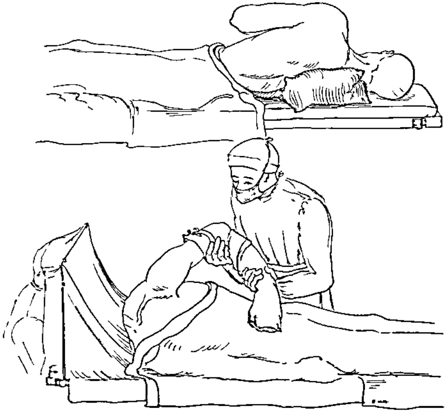


FIG 722 Position of patient for shoulder operations Torso must be so turned that the point of the affected shoulder is uppermost Head and face are turned away from field as far as possible Entire arm and chest must be prepared, and whole arm so covered that it can be easily manipulated It is useful also to thread arm through opening in a laparotomy sheet It is assistant's duty to manipulate extremity to facilitate good exposure.

may greatly shorten the convalescence. Any form of treatment should include relief of tension upon the plexus and should put the muscles of the shoulder at rest. This means recumbency in bed with the arm in abduction and external rotation.

Operative Approach to Shoulder. Operation upon the shoulder requires a rather special technic.

1. ANESTHESIA.
   a. LOCAL. Applicable to simple incision of subacromial bursa.
   b. GENERAL.
      1. Necessary for repair of supraspinatus tendon.
      2. Repair of long head of biceps.
      3. Open reduction of surgical neck of humerus.
      4. Tendon transplant for recurrent dislocation of shoulder. (Nicola operation.)
2. POSITION (Fig. 722).

The patient is placed on his back on the table. A large sandbag is placed under the shoulder blade so that the body is tilted about 45°; another sandbag is placed under the corresponding hip. The head is turned toward the opposite shoulder. The entire shoulder and upper arm are prepared and the forearm and hand are covered with a sterile pillowcase The arm is then drawn through the hole in a laparotomy sheet Two assistants and a nurse comprise the necessary team.

INCISION From the anterior tip of the acromion, following the fibers of the deltoid in the general direction of the bicipital groove, a one-and-a-half- to two-inch incision is adequate for inspection. With narrow retractors in the wound and utilizing traction and rotary motions of the arm, it is possible to expose the supraspinatus tendon, long head of the biceps, and the infraspinatus tendon If greater exposure is needed the acromion may be cut with a chisel in the sagittal plane and the tip retracted outward

It has been the author's experience that the second assistant who manipulates the arm is quite the most important person in the operation.

Recently the author has had specially made Gallie needles about a half inch long, full curve. With these needles it is possible to work between the head of the humerus and the acromion and set the necessary sutures for repair of tears of the roof of the shoulder joint. [*See Chapter 42.—Ed.*]

CLOSURE OF WOUND. The joint capsule is closed with silk, the subcutaneous tissues similarly, and the skin with cutaneous sutures.

POSTOPERATIVE TREATMENT. Recently the author has prepared a plaster-of-paris splint before operation which holds the arm in 45° flexion, 45° abduction, and 45° external rotation; that is, the position of salute. Immediately following the operation, this plaster shell is applied and bandaged in position with cotton elastic bandages. After the skin sutures are removed, stooping exercises can be carried out with the plaster splint in place. After about three weeks the splint is removed and stooping exercises are encouraged. These exercises are followed by progressive active exercise (Fig. 716).

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30

Fractures of Humerus

JOHN A. CALDWELL, M.D.

GENERAL DISCUSSION

For purposes of discussion the humerus will be considered as divided into (1) upper end, (2) shaft, and (3) lower end. In considering the first of these divisions, reference will be made to the head, the anatomic neck, the surgical neck, the greater tuberosity, and, in children, the upper epiphysis. In the discussion of the shaft lesions, the division will be into fractures of the upper, middle, and lower thirds. Fractures of the lower end of the humerus are also considered in Chapter 31 on Fractures and Dislocations Involving Elbow Joint. (See Chapter 31.)

UPPER END OF HUMERUS

(See also Chapter 29)

Any fracture about the upper end of the humerus implies trauma about or transmitted to the shoulder joint. Careful differentiation of the various possibilities is very important.

For a proper examination the patient should sit erect with both shoulders exposed. Particularly to be noted are swelling or atrophy of the soft tissues over the shoulder and the presence of abnormal prominences or absence of normal prominences. An important finding which should always be sought is inward deviation of the axis of the humerus. The axis of the humerus in normal position passes from the center of the elbow crease below through the acromioclavicular joint above.

Palpation may disclose point tenderness, Stimson's sign, or crepitus. By flexing the forearm and using it as a lever in one hand to gently rotate the shaft while holding the head between the thumb and fingers of the other hand, one determines if the head rotates with the shaft or if crepitus is associated with this movement.

Stimson's sign (pain at the site of fracture on pressure in the long axis of the bone) is often useful when swelling is so extensive that direct palpation yields no definite information.

X-ray films should be stereoscopic anteroposterior ones for the reason that films taken in a lateral plane require abduction to nearly a right angle—a degree of movement which may not be possible on account of pain, or which might further displace fragments. [With care and gentleness anteroposterior views in external and internal rotation can often be secured. If it is possible to get these pictures, they may prove very helpful.—Ed.]

Fracture of Greater Tuberosity. These may result from direct violence or by avulsion. It is frequently associated with dislocation of the head of the humerus. The condition is difficult to diagnose, as a rule, except by x-ray. When the fracture occurs, the detached fragment is usually pulled backward and upward by the supra- and infraspinatus and teres minor muscles.

[When the displacement mentioned in the text as "usual" is present it is slight, or at

the most extremely moderate if the case is to be amenable to conservative treatment The vast majority of greater tuberosity fractures occurring without coincident shoulder dislocation show practically no displacement In those complicating shoulder dislocation the reduction of the dislocation returns the tuberosity to practically normal position in the great majority When splint This position they feel should be maintained for at least four weeks and two weeks more should elapse before any forceful active movement is made This position is uncomfortable and frequently very painful and nearly always requires confinement to the house Furthermore when the condition occurs simultaneously with a dislocation the abducted position is unfavorable

FIG 723 A

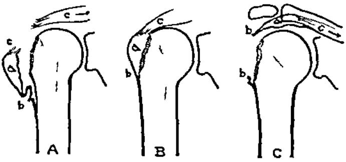


FIG 723 B

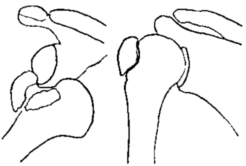


FIG 723 A Positions which greater tuberosity may assume following fracture or following dislocation of humerus associated with fracture of greater tuberosity after dislocation has been reduced

(A) Periosteal attachment intact but stripped from shaft and with associated tear of supraspinatus or infraspinatus attachments of musculotendinous cuff of shoulder joint capsule A relatively rare lesion Requires operative repair or cuff lesion with fastening of tuberosity

(B) The usual situation Both periosteum and cuff attachments are intact Shaded gap between tuberosity and shaft may be wide or narrow depending on amount of intervening hemorrhage and exudate and its consistency

(C) Periosteal attachment is torn and intact cuff attachment pulls tuberosity upward and back to or beneath acromion and clavicle by muscular contraction This requires operation with replacement (a) Tuberosity (b) periosteum (c) musculotendinous cuff

FIG 723 B Avulsion of greater tuberosity with dislocation of head of humerus Showing replacement of fragment which takes place when arm is bound to side after reduction of dislocation

marked displacement of the tuberosity is present, either without dislocation or after reduction of a dislocation it has the significance denoted in Fig 723 A

These marked displacements constitute a small percentage of the cases but their net result if neglected is the same as that of extensive tear of the musculotendinous cuff —Ed]

It is felt by many observers that the most logical position for the arm is in abduction and external rotation fixation being by circular plaster or some type of airplane for maintenance of reduction of the dislocation

We have several times been compelled by expediency to bind the arm to the side in cases of dislocation of the head of the humerus associated with avulsion of the greater tuberosity (Fig 723 B) Radiographs taken within the next few days nearly always showed considerable separation between the fragment and its seat, but after a lapse of several days when spasm of muscles had subsided the fragment would be found to have resumed the seat from which

it had been detached. Wilson mentions similar experience with this type of injury.

Guided by this experience, we usually try fixation with a swathe at first, and if this is not followed by replacement we favor open fixation of the detached fragment. [In those not requiring operation, the use of a sling and swathe for 48 or 72 hours with concomitant physical therapy (heat—massage—low-milliamperage diathermy) can be followed by a sling during the day only, with a swathe added at night, and by the institution of pendulum exercises several times a day (Chapter 29), gradually instituting active exercise as described below for fractures of the upper end of the humerus The sling usually can be discarded in from ten days to two weeks, and the swathe at night can be discarded in from two to three weeks Physical therapy merely as an adjuvant, and progressive active use as the main line of therapy, constitute the further treatment. More prolonged or extensive immobilization than described in this note, or the use of plaster or of airplane splints, is condemned by an increasingly large group. When dislocation has been present the night swathe is used for a longer time, and active exercise at the shoulder is kept below the right-angle level for from four to six weeks Otherwise the treatment is the same.—Ed.]

This injury is sometimes followed by a bursitis which is extremely incapacitating and painful. [For this condition, see Chapter 11.—Ed]

Fracture of Anatomic Neck. These usually occur in elderly patients as a result of direct violence or falls on the outstretched hand or elbow. It is frequently impacted, but when this is not the case the fragments are not often displaced to any marked degree. When displacement is present it may be of extreme degree.

Fracture of Surgical Neck. This is of frequent occurrence, and is seen in all ages It is commonly produced by falls on the abducted arm. The lower fragment may be displaced medially into the axilla, laterally or anteriorly. Posterior displacement is not common. Impaction, with rotary or angular deformity of the head on the shaft, is the commonest displacement

On examination diffuse swelling is usually extreme. The axis of the humerus may deviate inward, and the presence of this sign with retention of the normal rounded contour of the shoulder *differentiates this* fracture from a dislocation In addition, the head does not rotate with the shaft of the bone and rotary movement of the shaft elicits crepitus.

Attempts to reduce this fracture are unsuccessful in many cases because the rounded head covered by a soft muscular mass is difficult to control. Abduction to 60° with rotation of the shaft is usually the most successful maneuver [Adduction of the shaft with forward elevation of the elbow and concomitant traction and direct manipulation often succeeds when the procedure just described does not.—Ed] When manipulation does not put the fragments in apposition, prolonged traction with the arm abducted to from 45 to 60°, and with the elbow flexed to 90°, will often result in anatomic replacement of fragments This position relaxes the biceps tendon as well as the deltoid muscle and the external rotators attached to the greater tuberosity, while abduction to no more than 60° does not stretch the pectoralis major to an embarrassing degree

Separation of Upper Humeral Epiphysis. This is seen at all ages up to 20 years It occasionally occurs as a birth injury, but is most frequent during the second decade when activity is greatest Symptoms, signs, and examination are the same in every particular as for fracture of the surgical neck. It is not possible to differentiate this condition from fracture without x-ray. The difficulties of reduction are just as great and as uncertain as for fractures of the surgical neck, but accurate approximation of the two fragments is much more important in the case of separation of

the epiphysis because of the possibility of subsequent growth disturbance

Treatment of Fractures of Upper End of Humerus

Transportation For transportation binding the arm snugly to the side with a swathe usually permits comfort except in those cases where there has been gross displacement with laceration of soft tissue In such event some form of traction splint such as the Murray Jones traction splint (Fig 724) or the Jones humeral traction (Fig 725) splint may be necessary [See Emergency and First aid Treatment in Chapter 22 —Ed]

Reduction For reduction local anesthesia is usually satisfactory 20 to 30 cc of 2 per cent procaine being injected into the hematoma about the fracture and no manipulation attempted for ten minutes [See Chapter 22 for technic —Ed] Local anesthesia is a distinct advantage in manipulation of any fracture of the humerus because after the fracture has been reduced any form of humeral dressing is much easier to apply if the patient is conscious and sitting up A plaster spica for the arm and shoulder is otherwise quite difficult to apply unless special apparatus is at hand for the patient to recline on The same applies to an adequate sling and swathe When accurate or satisfactory apposition of the fragments can be secured fixation by the chosen apparatus should be immediate It is always desirable for the patient to remain ambulatory and if possible to wear street clothing and carry on his occupation

Traction When it has not been possible to manually reduce the fragments to a satisfactory position some form of traction is usually applied This may be one of the apparatuses which permit the patient to be about, such as a Jones humeral traction splint or the Hoke apparatus (Fig 726) The former permits traction only in a vertical direction, but when the latter is employed any degree of abduction in plaster is possible

Balanced Traction If because of feebleness, obesity or other injuries the patient must be confined to bed some form of balanced traction is the best method We have found it advantageous to use a Thomas leg splint with a small padded ring The elbow

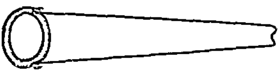


Fig 724 Murray Jones arm splint —a particularly useful transportation splint can be applied over clothing

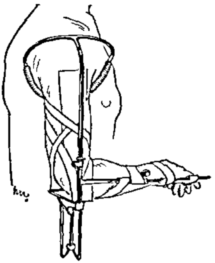


Fig 725 Jones traction splint for fractures of humerus most frequently employed as temporary splint (Courtesy Zimmer Mfg Co Warsaw Ind)

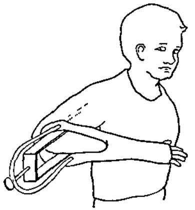
is flexed to 90° and both arm and splint are suspended and counterbalanced under a Balkan frame (Fig 727) Traction may be made by means of a sling about the upper end of the bent forearm by adhesive plaster strips applied along each side of the humerus to the shoulder or by a Steinmann pin or Kirschner wire through the olecranon A sling about the forearm is apt to compress the vessels somewhat and to thus impair circulation and cause the hand to swell

Adhesive plaster stretches the soft tissues and may cause a dermatitis which will prevent open operation if traction proves unsuccessful. In every way a pin or wire through the olecranon is the most comfortable and effective way of applying continuous traction to a humerus. The elbow should always be flexed and the arm abducted 45 to 60° since in this position the biceps and other tendons which bridge the fracture are relaxed. The method of overhead traction by a pin through the olecranon is frequently effective See Chapter 31

Magnuson utilizes the flexed elbow and a special traction piece over the front of the elbow. See Fig. 750, p. 891.

The indications for reduction in these cases of surgical- and anatomic-neck fractures are a matter of considerable dispute, and the test of time, and adequate follow-up on results, seems to be slowly but steadily leading to a consensus that reduction is indicated only in a minority of cases

In anatomic-neck fractures with impaction and angulation as the deformity it is pretty generally agreed that reduction is not indicated, and that the case should be treated as described for greater tuberosity fractures in the editorial note on p 852.



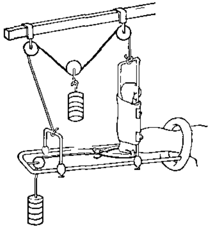


FIG. 726. (*Left*) Hoke apparatus. Useful to apply traction on humerus when plaster case is used. Adhesive strips in illustration. A pin through olecranon can also be used (Courtesy, Zimmer Mfg Co, Warsaw, Ind.)

FIG. 727. (*Right*) Arrangement for balanced traction of humerus with small Steinmann pin through olecranon

In anatomic neck fractures with actual marked displacement of the head from the shaft, with or without coincident tuberosity fractures, reduction and after-treatment by any of the means described by the author of this chapter are advocated by many surgeons. An increasing number, however, are becoming convinced that the best method of treatment in these cases is primary excision of the head fragment, placement of the smoothed-off end of the shaft in the glenoid, and the early institution of active motion in balanced suspension. This is continued for from two to three weeks, and the patient then becomes ambulatory with a sling and the institution of the regimen described for greater-tuberosity fractures as designated above. Apart from the empirical results observed in follow-up on these cases, the basis for this viewpoint lies in the difficulty of reduction and the fact that in anatomic-neck fractures the head fragment has extremely little if anything in the way of soft-part attachments As a result, delayed or nonunion is common, and even if union does occur there is apt to be some degree of

aseptic necrosis or slow degenerative change in the head fragment leading to a flattening and mushrooming of the head fragment within the next one to five years For the first year these patients may show excellent functional results this is followed by a gradually progressive loss of motion range with increasing discomfort and pain associated with the x ray changes noted above If the tuberosities remain attached to the head fragment and displace with it the condition is not of course an anatomic neck fracture and replacement in reasonable realignment is indicated followed by the institution of pendulum exercises and gradually increasing active motion at as early a date as possible

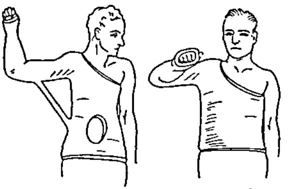
See Chapter 22 in regard to the whole question of reduction of epiphyseal displacements

In surgical neck fractures the tuberosities remaining with the head fragment and the fracture being through the lower portions of the tuberosities mere angulation even when marked with impaction can be treated with excellent cosmetic and functional results by the sling and swathe pendulum exercise and early active motion regimen already prescribed without reduction of the deformity

When the shaft and the upper fragment are completely or largely out of contact then reduction by either the closed or open methods with replacement of the upper fragment and after treatment as described by the author is indicated

In children the surgical neck fracture is represented either by epiphyseal separation which see or by what are really high shaft fractures with angulation If the child is under ten years of age and the angular deformity is less than 15° correction of the deformity is probably not necessary, as growth tendencies will take care of it All that is indicated is protection for four to six weeks to prevent additional trauma or deformity If the angular deformity is more than 15° in a child under ten years of age or if it is of any degree sufficient to produce visible deformity in a child over ten years it is perhaps wiser to correct it and to maintain correction as previously indicated — Ed]

Open Operation When neither manipulation nor traction succeeds in accomplishing satisfactory reduction an open operation should be considered For this purpose the exposure described by Henry is probably the most satisfactory The line of the



a *b*

FIG 728 Plaster cases with arm in abduction (*a*) Arm braced and humerus rotated (*b*) Arm not braced and humerus not rotated outward (Courtesy Speers A Brief Outline of Modern Treatment of Fractures p 54 Baltimore Williams & Wilkins Co)

incision is from the acromion process to the outer condyle of the humerus The deltoid muscle and long head of the biceps are separated and the head and neck of the humerus are exposed

There has been much controversy as to the position in which a fracture of the humerus near the shoulder should be splinted and the disagreements may be said to have been resolved into two opinions The first of these might be called rigid immobilizationists and the second those who believe that early active motion is the preferable method

Those who advocate complete restriction of movement in the shoulder joint resort to a plaster case (Fig 728) or some variety of

airplane splint (Fig. 729), with the arm abducted 60 to 90° and externally rotated 90 to 180°. In this position the deltoid muscle is relaxed, as are also the supra- and infraspinatus and teres minor. When reduction has not been manually accomplished and some form of traction must be used,

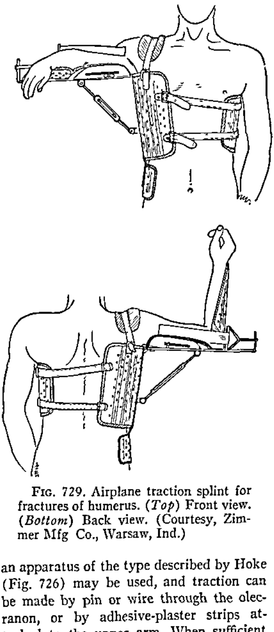


FIG. 729. Airplane traction splint for fractures of humerus. (*Top*) Front view. (*Bottom*) Back view. (Courtesy, Zimmer Mfg Co., Warsaw, Ind.)

an apparatus of the type described by Hoke (Fig. 726) may be used, and traction can be made by pin or wire through the olecranon, or by adhesive-plaster strips attached to the upper arm. When sufficient calcification of callus has taken place to render the site of fracture immobile, the fixation is removed and function is restored by massage and by passive and active motion.

The advocates of this line of procedure advance the following arguments Since the deltoid muscle is relaxed, it is not stretched. This is also true of the external rotators The movements of abduction and external rotation, which are the most difficult to restore, are diminished to a lesser degree by this position, and consequently return more promptly.

Objections to this method are that (1) the apparatus is heavy and cumbersome, (2) street clothing cannot usually be worn, which necessitates confinement to the house, and (3) such a dressing as a shoulder spica holding the arm in abduction requires that the body be encased to the waist, which is out of the question for the feeble or obese patient.

The second method consists in some form of dressing which permits the arm to hang at the side and which uses the wall of the thorax, either directly or with some interposed material or device, as support to prevent lateral motion. Since the shoulder is a ball and socket joint and permits the humerus to rotate freely in all directions, the bone will hang vertically, influenced by gravity alone, when the patient is erect and the arm at rest The common splinting devices are (1) a swathe, of either fabric or adhesive plaster, to include the humerus *and thorax, with a well-powdered towel interposed* between the arm and the chest wall to prevent skin maceration, or (2) a Jones humeral traction splint. It is rarely necessary to confine the arm fully for more than a week or ten days, after which time some active exercises are begun These should first be gentle rotation of the humerus, using the flexed forearm as a lever. After a few days the arm should be held at the side with the elbow extended and swung back and forth through as great an arc as is comfortable (Fig. 730). A few days later the patient may lean forward and abduct and

adduct the arm across the body within comfortable limits (Fig 731)

Such a regimen should be carried out for from four to six weeks at which time union will usually be firm enough that moderate stress on the fracture will be painless and all movements of the hand below the shoulder can be made comfortably With the use

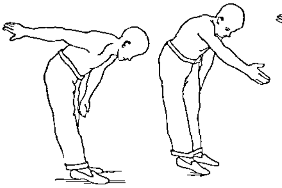


Fig 730 Active exercises to restore motion Flexion and extension

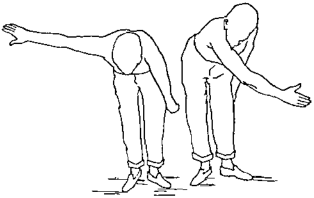


Fig 731 Active exercises to restore motion Abduction and adduction

of exercises such as crawling up the wall with the hands (Fig 732) or abducting and adducting the arm against the counter force of a weight pulling through an over head pulley or swinging the arm forward and backward and across the body shoulder function will in most cases be restored in from 8 to 12 weeks The variable factors which prolong this period are the age and physical condition of the patient lack of cooperation and persistence in carrying out restorative movements the type of fracture and the accuracy of reduction

SHAFT OF HUMERUS

Fractures of the shaft of the humerus may occur at any location Those toward the upper end are as a rule due to indirect violence while direct trauma is usually responsible for those about the middle Comminution is frequent and compound fractures are often seen Wrestling and other physical contests of strength and occasionally torsion of the forearm while throwing result in a long spiral fracture most commonly located about or below the middle of the bone The humerus is one of the bones most frequently subject to gunshot fracture

Diagnosis of fracture of the humerus is almost always quite obvious—swelling appears early and is very evident and abnormal mobility is noticed with slight movement Crepitus is generally elicited on the slightest movement unless displacement has been sufficient to force one fragment into a different muscle plane from the other and the interposed muscle prevents contact of

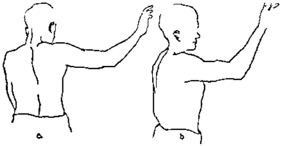


Fig 732 Active exercises to restore motion Crawling up wall with hands (a) Sideways to wall (b) facing wall

the fragments If no crepitus or obvious bony contact of fragments is elicited during examination or attempted reduction interposition of soft parts between the fragments and the advisability of open reduction is apparent

In a fracture of the shaft of the humerus, if the break is not comminuted or if the obliquity is not too great, reduction of fragments is probably easier than in any other fracture. Maintenance of apposition of fragments is most uncertain, however, and subsequent displacement is always to be guarded against by frequent checks by x-ray or by fluoroscopic inspection.

Anesthesia for manipulation and splinting is most satisfactory with 2% procaine injected into the hematoma between the fragments. Following this, ten minutes is allowed to elapse before any attempt at manipulation, and reduction and splinting can nearly always be accomplished without discomfort to the patient. Occasionally one encounters an individual who is temperamentally apprehensive and who cannot relax, and no choice is left for the operator but general anesthesia. [Brachial block can be employed It requires a skilled anesthetist, and if not complete it is worse than useless. It is not a procedure for everyday use.—Ed.]

When fixing a fracture of the shaft of the humerus, regard must be had not only for the nature of the injury, but also for several other factors. Is the patient a child or an adult? If the latter, is he vigorous or feeble, slender or obese? Does he live alone, or can he receive simple nursing care and personal attention? Is his injury severe, or is it associated with other injuries, so that confinement to bed will be necessary? Will the patient be able to rest and abstain from activity during convalescence, or is it necessary that he get about somewhat? Obviously, all of these questions must be considered before one decides upon an apparatus for fixation.

Transportation. For transportation there are three methods which will enable a patient to move or be carried without painful displacement of fragments. [See Emergency and First-aid Treatment in Chapter 22.—Ed.] The simplest is a swathe which binds the patient's arm snugly to his side, the forearm being held at a right angle by a sling If the arm be put in the sling first, and the swathe applied over the sling, rotation of the humerus is prevented The sling in this case should not cover the entire forearm, but had better be a wide strip of bandage (four-inch) which is tied loosely about the wrist. If it is felt that some traction is necessary, as is the case when the fracture is comminuted or spiral or very oblique, a Jones humeral traction splint or a Thomas arm splint should be applied. The Jones splint may be permitted to remain for some time and may be used for treatment as well as transport. A Thomas arm splint is unusuitable for prolonged use because it holds the arm extended at the elbow. This position does not permit adequate relaxation of the muscles which bridge the fracture .

When fixation in an abducted position is necessary because of persistent adduction of the lower fragment, one of the airplane types of splint may be used, or a plaster spica may be applied with the arm in the abducted position and as much external rotation as is indicated by x-ray study. Such a dressing is cumbersome and is, as a rule, impractical in patients who are obese or feeble. It has the further disadvantage of preventing the wearing of ordinary street clothes

When the fracture is high, that is, well above the insertion of the deltoid muscle, the simplest dressing is the body swathe, with the forearm suspended in a sling with the elbow at 90°. For the first 10 to 14 days the sling should be covered by the swathe in order that the arm shall not rotate. Later the sling may be removed from the confinement of the swathe and the patient directed to rotate his arm within comfortable limits. [See previous notes on after-care.—Ed.]

When the fracture is spiral or the surfaces have so much obliquity that they cannot be made to engage, some form of traction must be used to maintain length. If there is no contraindication to confinement

of the patient to bed, the simplest and most comfortable way is by means of a pin through the olecranon with the arm counterbalanced under a Balkan frame and the forearm flexed at 90° With this method the effect of traction and position are observed by portable x ray examinations

arm is sufficient in most cases to pull the lower fragment down some device to restrict lateral motion and rotation is all that is required to make fragments come together in the muscular tube in which they lie Fig 733 illustrates four dressings which have been in use for years, but which are

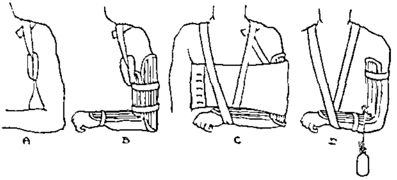


Fig 733 Types of splinting in use at various times

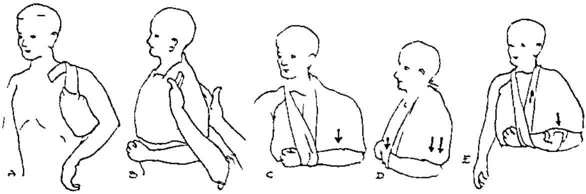


Fig 734 Gurd dressing for fracture of humerus
(A) Axillary pad to abduct arm in position
(B) Plaster applied and molded to contour of arm
(C) Shows direction of pull
(D) Lateral view
(E) Felt pad in position This acts as a fulcrum when forearm is used as lever to pull on humerus, and protects forearm from pressure

When the patient is ambulatory, traction may be made by a Jones humeral traction splint or Hoke apparatus However, either apparatus is cumbersome and prevents wearing of clothes, and is really not necessary because very little pull is required to overcome overlapping of fragments Since the humerus hangs vertically when the patient is upright and since the weight of the arm below the fracture added to the fore difficult to maintain or only partially effective

There are two simple and excellent methods of accomplishing the purpose The first is the plaster swathe of Fraser Gurd which can be used for both fixation and traction (Fig 734) The arm is bandaged to the side by means of plaster of paris rolls which also cover the shoulder A well powdered towel is interposed between the arm and the thorax

to prevent maceration of the apposed skin surfaces. A pad of felt is then placed just below the bend of the elbow between the flexor surface of the forearm and the lower edge of the plaster encasement. This pad acts as a fulcrum when the wrist is drawn up by a sling around the neck, and the lower fragment of the humerus is drawn down.

The other method is the author's hanging cast, or traction cast (Fig. 735). A plaster

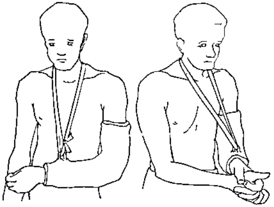


FIG 735 (*Left*) Swinging cast of author. Weight of cast restricts movement and makes traction on humerus. Note suspension from wrist only.

FIG. 736. (*Right*) Rotation with traction cast. This exercise may be started early (first week). Since both fragments rotate through same arc, they are not displaced.

case is applied from axilla to wrist with the elbow at 90°. This case should not be applied to the skin, but over stockinet, no padding being used. A ring of metal is incorporated in the upper surface of the case *at the wrist*, and through this is threaded a strip of muslin bandage which goes about the neck, and by means of which the arm is suspended. This apparatus restricts movement to a sufficient extent to prevent gross displacement and the weight of the case will be sufficient to pull the lower fragment down into line with the upper. [The constant traction supplies sufficient immobilization in these cases to allow of union. It is essential that the suspension be by the wrist, and not by a sling under the whole forearm or supporting the elbow The wrist should be held up so that the weight of the arm and plaster pulls directly downward at the elbow. Traction may be applied to the elbow portion of the plaster down over the foot of the bed at night, or the patient may sleep in a semi-reclining position to maintain the downward traction effect of the forearm and the encasing plaster —Ed]

Whatever the splint or case that is worn, it should be continued for six weeks, after which a sling will give sufficient immobilization unless union has been considerably delayed. Even if some false motion can be elicited, a sling usually gives sufficient restriction of motion, and displacement or angulation is not apt to occur because the bone hangs vertically, and the weight of the arm will keep the fragments aligned After removal of the splint, the exercises described earlier should be instituted, as well as gentle use of the hand and forearm.

Fracture of the shaft of the humerus is occasionally associated with injury to the radial nerve, particularly when the break is in the middle third of the bone When the patient is first seen an examination to discover or eliminate radial-nerve injury should be made, and this examination should be repeated from time to time. The cardinal symptoms are wristdrop (inability to extend the wrist), inability to abduct the thumb, and sensory loss over the dorsum of the thumb and the radial side of the wrist. Radial-nerve lesions may be early or late The early lesions may be contusions or lacerations of the nerve from its having been stretched by excessive angulation of the bone, or bruised by pressure from displaced fragments. Complete lesions consist of severance of the nerve by sharp fragments either at the time of injury or by subsequent manipulations Late involvement of the radial nerve is due to the nerve being caught and incarcerated in the fibrous tissue or callus which has been deposited to effect repair.

When examination soon after injury shows complete loss of extensor power in the wrist and inability to abduct the thumb with anesthesia in the area supplied by the radial nerve there is no way of telling whether the interruption of conduction is anatomic or physiologic or in other words whether the nerve is severed or conduction is interrupted by hemorrhage and edema following contusion The only ways in which this question can be decided is by exploration or by waiting for return of function The latter course requires four to six weeks before the question can be answered and this time is lost if it turns out that the nerve has been severed For this reason we feel that when the symptoms indicate complete interruption exploration should not be delayed In case nerve severance is found repair is easier at this time and at the same operation the fracture may be fixed by plate wire band or other mechanical measure [See Chapter 22 for operative fixation —Ed] When the symptoms indicate an incomplete nerve lesion a policy of waiting should be pursued Nearly all contusions of the nerve are followed by recovery which may be complete by the time the fracture has united

Supracondylar Fracture of Humerus [See Chapter 31 for other and different views on this subject —Ed] Usually this fracture occurs in children and a separation of the epiphysis is frequently seen instead of a fracture or the fracture line follows the epiphyseal line part of the way The fracture line is nearly always oblique with the lower fragment displaced posteriorly Swelling usually follows so promptly after injury that any deformity is masked Usually however the lower fragment is displaced posteriorly so that the altered contour is similar to that seen in posterior dislocation of the elbow Frequently lateral displacement of the distal fragment is associated with the posterior one There is often angulation and false motion noticed just above the elbow and flexion of the elbow is difficult or impossible because of pain

Complete relaxing anesthesia is always desirable and usually necessary to effect accurate reduction Local anesthesia usually is excellent The maneuvers are as follows One hand grasps the patient s wrist and the other the humerus—just above the elbow The latter hand is placed so that the palm covers the posterior surface of the humerus and the fingers the anterior surface while the thumb is on the olecranon process The patient s arm is then hyperextended and traction is exerted in the long axis of the bone and while the pull is continued the elbow is gradually flexed as far as possible

Complete flexion is rarely possible on account of swelling of the soft tissues Forcing of flexion will often result in compression of the brachial artery to such degree that the radial pulse will be obliterated When this is noted the flexion should be slowly decreased until the pulse reappears As swelling subsides flexion should be increased until the fragments are held in satisfactory position

Acute flexion of the elbow stretches the triceps tendon tightly over the fracture This not only draws the fragments together but by its close apposition to the posterior surface of the humerus prevents backward displacement of the distal fragment Compression of the soft tissues on the front of the humerus holds the proximal fragment back This anatomic arrangement of the joint structures favors retention of the fragments in position when the elbow is acutely flexed So effective is this position for maintaining reduction that sometimes the only dressing necessary is one to keep the elbow acutely flexed This plan of treatment was emphasized by Hugh Owen Thomas and his gage halter is probably the most used as well as the simplest dressing for this type of fracture The hand is put in the throttling position that is grasping the throat and is fastened in this position by

means of a wide muslin bandage tied around the wrist and the neck.

The Robert Jones dressing consists of a wide strip of adhesive plaster about the middle of both the arm and the forearm, holding the arm in acute flexion. The hand is supported by a loop of bandage about the wrist and the neck. The adhesive plaster about the arm is uncomfortable, and if swelling increases it may become perilously tight; it really accomplishes no more than the gage halter of Thomas.

The Ashhurst dressing is an excellent one, consisting of a figure-of-eight bandage holding the forearm in acute flexion. The tails of the bandage are left long at the wrist and tied about the neck.

Immediate fixation in acute flexion is frequently not possible when the arm is first seen because, in the presence of much swelling, flexion of the joint will cause compression of the brachial artery and cut off the circulation of the hand and forearm. Also, the prompt appearance of fracture blebs will cause the apposed surfaces to macerate if they are compressed together. When acute flexion is not possible, the best procedure is to splint the arm in almost complete extension by means of a molded plaster splint which extends beyond the fingers. The patient should then be put to bed and the arm suspended at a right angle to the body while the patient is recumbent. In this position swelling will usually subside enough in three or four days to permit reduction. [See comments on this procedure in Chapter 31.—Ed.]

After reduction of a supracondylar fracture the patient should be under close observation for at least 72 hours The arm should be kept in acute flexion for four weeks. At the end of the fourth week the flexion should be diminished to 90°, and the next week should again be brought up to the acute position. In six weeks all dressings may be removed and light exercise permitted. Under active use, complete extension will usually be possible in two to three months, though occasionally it will take the patient many months to be able to extend the arm beyond 165 or 170°

LOWER END OF HUMERUS

Epiphyseal separation is similar in all particulars to supracondylar fracture. As a rule the injury is not a straight simple detachment of the epiphysis from the diaphysis at the epiphyseal line, but frequently a portion of the diaphysis will displace with the epiphysis. When the injury occurs very early in childhood, the diagnosis may be obscured by the fact that since the epiphysis is still cartilaginous, it is not seen by x-ray and its displacement cannot be discovered except by palpation Reduction and management are similar to that described for supracondylar fractures, and when fair apposition has been secured a good functional result usually follows. Inaccurate reduction may be followed by retardation of growth of the bone and some shortening, or, what is more serious, by irregular impairment of growth and development of the distal end of the bone, resulting in deformity and possible functional impairment. [See Chapter 22 for discussion of epiphyseal separation and growth disturbance.—Ed.]

Fracture of a single epicondyle is rarely an injury of any portentous significance The fracture does not extend into the elbow joint and the pain associated with movement is nearly always sufficient to insure adequate restriction of motion The usual disability which follows these injuries is most commonly due to prolonged splinting A short period of splinting in flexion should be followed by increasing active motion

When the inner epicondyle is displaced it is always possible that the ulnar nerve may be caught in callus or scar tissue and cause some disability of the hand from interference with ulnar conduction. When this happens, removal of the epicondyle and neurolysis of the ulnar nerve should remedy the condition.

Fracture of a condyle of the humerus may be of trivial significance when the fragment is not large and its separation does not produce a defect in the surface of the trochlea when the inner condyle is involved or of the capitellum when the external condyle is separated Treatment consists in acutely flexing the elbow and holding it in this position until union takes place—usually about four weeks in children and six weeks in an adult When roentgenograms show that this position does not effect replacement open fixation should be considered This is done by a lateral incision and the muscular attachments are freed from the surface of the bone by sharp dissection The displaced condyle is then fixed by means of a nail bone peg loop of wire or heavy catgut In an adult, when the fragment is not too large the better plan is often to remove the fragment instead of attempting to anchor it back in position because the prolonged immobilization of the elbow which is necessary to secure union of the dislodged piece may result in greater dysfunction of the joint than would absence of the bony prominence In children fixation of the fragment offers greater chance of successful union of the fragment

No condyle should be allowed to remain displaced very far from its normal site because attempts at repair may involve the deposit of a mass of callus large enough to impair free motion of the elbow

Fractures of a condyle into either trochlea or capitellum or a fracture separating one of these structures from the other are injuries with serious possibilities The two major immediate sequelae are (1) lateral deviation of the elbow causing change in the carrying angle and (2) interference with the normal range of motion with weakening of the arm and pain on lifting or carrying weights

Replacement of the fragment should be attempted in the following maneuver The injured arm is grasped just above the elbow by one of the operator s hands while the other hand grasps the patient s wrist The elbow is then hyperextended and also bent away from the side of the displaced condyle Traction is made with the arm and forearm thus hyperextended and adducted or abducted at the elbow and the joint is gradually flexed while the pull is maintained If good replacement cannot be accomplished the broken condyle should be replaced by open operation and fixed in position by screw, bolt or peg through the condyle, or by wire or a loop of absorbable material Whatever fixation is used should be strong enough to hold the fragments without requiring splinting of the elbow Personally we like to apply a Schantz dressing to the elbow and hang the forearm in a sling at 90° The patient is then encouraged to move the elbow gently as soon as he can do so without pain

Fracture of the condyles occasionally causes interference of conduction in the ulnar nerve When the fracture is of the inner condyle the nerve may be lacerated pinched or stretched at the time of injury by the displaced fragment On the other hand symptoms may appear late due to incarceration of the nerve in callus or scar tissue or due to stretching several weeks or months after injury

When a detached external condyle is not replaced and an increased carrying angle results the bones of the forearm gradually slip toward the outer side of the humeral joint surface This migration of the forearm will in time make enough tension on the ulnar nerve to interfere with the finer movements of the hand and with deformity and atrophy of the ulnar type in the intrinsic muscles of the hand This type of ulnar nerve involvement may not appear for some years after the injury, often being delayed for as long as ten or more years

The radial nerve is not often involved in fractures of the external condyle but this is occasionally so In one personal case the nerve was severed when caught between fragments during an attempt to manipulate

a displaced external condyle into position. When complete interruption comes on immediately after the fracture or during a manipulation an exploration should be done as soon as possible. With delayed or incomplete lesions of the nerve an expectant course may be followed, and late exploration done as soon as it becomes apparent that spontaneous recovery will not take place. The median nerve is rarely injured in lower humeral fractures, because of its position almost in the midline in the cubital space where it is surrounded by soft tissue When injury does occur, it is manifested by complete loss of flexor power in the hand and wrist and loss of sensation in the palm and the palmar surface of the fingers.

The rule of early interference in immediate or complete lesions and observation and late examination when symptoms are delayed should be followed The most serious complication of fracture of the lower end of the humerus is the ischemic paralysis which in extreme cases is followed by Volkmann's contracture or neuromuscular fibrosis. This condition, described by Volkmann in 1881, has been the subject of much speculation in the past as to both cause and pathologic changes The name neuromuscular fibrosis is a confession of pathologic uncertainty. The convincing piece of experimental research by Barney Brooks has made clear the pathologic changes and also cleared many physicians of charges of mishandling patients who have had the misfortune to be victims of this disaster. [See Chapters 22 and 31 for further discussion of this subject.—Ed.]

Operations for fractures in the lower end of the humerus may be done for malposition which cannot be corrected by manipulation and the purpose of correcting communication of fragments.

Correction of malposition and open fixation is rarely necessary in children. Gravity and use of the arm will in most instances restore a useful degree of function, even if accurate reduction cannot be made, if the arm is splinted or held with the elbow in safe flexion Occasionally the fracture surfaces will be so shaped that acute flexion displaces them instead of holding them. In such cases the arm should be fixed in the position in which the best reduction can be secured. If a mass of callus grows on the anterior face of the humerus, preventing flexion by the impingement of the coronoid process of the ulna on it, this mass should be removed with an osteotome some six months or more after the treatment has been discontinued This is a much more conservative and a safer procedure than an open fixation on a child at the time of fracture. [See comments on myositis ossificans in Chapter 22.—Ed]

Operative Treatment of Fractures Lower End of Humerus

Grossly comminuted fractures of the lower end of the humerus in which the fragments are irregular in shape and the surfaces very oblique can rarely be reduced. To re-assemble the displaced fragments with any degree of accuracy, prolonged traction by a pin or wire through the olecranon must be used with the forearm flexed to 90° and the entire arm counterbalanced. [See Overhead Pin Suspension in Chapter 31.—Ed.] When the trial of this method fails to improve the position of the fragments, an open operation offers about the only method by which restoration of the relations of the joint surfaces can be brought about. The prolonged use of skeletal traction may be followed by infection along the pin track which is within the operative field. It must be sterile beyond any suspicion before operation is undertaken When there is any doubt about traction being effective, we feel that the wiser decision is not to employ it, but to plan an open operation from the first. Manipulation of the fragments with traction on the humerus under anesthesia, while the effect of the manipulation is observed under the fluoroscope, may help one to arrive at a decision as to whether

or not traction will be followed by satisfactory reposition of fragments

We have found that the most satisfactory approach is from the posterior surface and the best position is with the arm flexed over the chest of the patient When the arm rests on an armboard the posterior surface of the which projects beyond the hand This stabilizes the elbow adequately and the weight is cut loose as soon as it becomes necessary to manipulate the elbow The incision should be at least six inches long above the elbow and two or three inches below, and should be to the medial side of the posterior mid

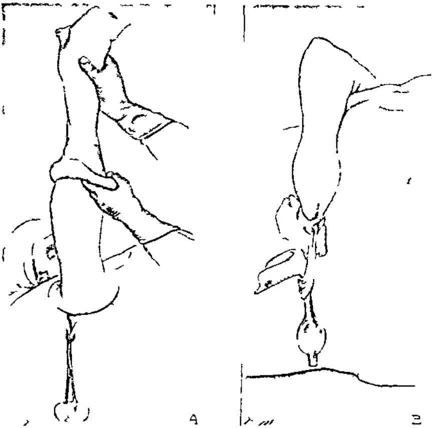


FIG 737 Operation for comminuted supracondylar fracture of humerus (A) Draping with two layers of autoclaved stockinet (B) Arm across chest held in position by weight tied to wrist

arm is not accessible Our custom is to sterilize the operative area, and then to cover the entire arm with two layers of stockinet which have previously been rolled into 'doughnuts' and autoclaved (Fig 737) The arm is then passed through a sheet with a hole in it and is flexed over the patient s chest During operative handling the arm repeatedly tends to slip off the chest We have found it very helpful to tie a sterilized weight (a weighted vaginal speculum answers perfectly) to that part of the stockinet line The diagonal fibers of the long head of the triceps should be separated from the triceps tendon down to the humerus The ulnar nerve should be located, dissected free, and retracted from the field by a wet tape Occasionally the skin can be retracted sufficiently to allow access to both sides of the humerus and the fragments can be manipulated in position without freeing muscles from both condyles Most frequently, however, it is necessary to cut the triceps tendon about one inch above the

FIG 738. Fragments exposed after longitudinal incision. Triceps tendon severed and retracted. Fragments clamped in uterine tumor forceps, and condyles being drilled for bolt

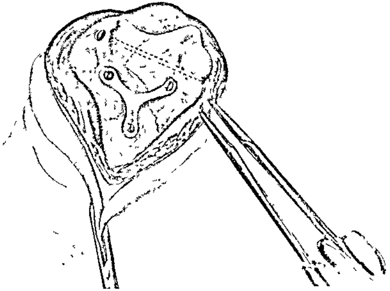


FIG. 739. Fragments secured by bolt through condyles and by three-armed plate.

olecranon and reflect the entire muscle mass from the posterior and lateral surfaces of the bone the dissection proceeding from above downward The triceps should not be cut through completely at one level but should be step cut that is cut halfway from one side then halfway from the op posite side at a different level and the internal ends of the cross incisions should be joined by a longitudinal incision

After the fragments have been freed from soft tissue they should be fitted together as accurately as possible and held in position For this purpose we have found a double uterine tumor forceps with a ratchet lock most valuable (Fig 738) With this instru ment the fragments may be held with little danger of cru hing and may be drilled for whatever fixation material is suitable for the particular case Our preference is for wire or plates to unite condyles to the shaft (Fig 739) For holding the two condyles together when there is a fracture separating them we have found a small steel bolt most useful This is usually of the size of a 6/32 bolt and is about four inches long and threaded the entire length A proper sized drill is drilled through the humeral condyles from one condyle to the other When the drill point emerges the drill is unchucked and the bolt with a nut next to the chuck is clamped in the chuck The drill is care fully and gradually withdrawn with pliers and the bolt is spun through the drill hole following clo ely upon the removal of the drill When the end of the bolt emerges a nut is started on the end and clamped down tight This method makes for secure fixation of the separated condyles and the bolt is easy to remove at a future date Since the condyles and lower shaft are cancellous bone, screws into the bone strip easily and do not hold well Loops of wire preferably of stainless steel are very useful provided the wire is twisted down tight Nails and beef bone pegs are occasionally suitable to anchor a detached condyle

After a comminuted fracture of the hu merus has had an open operation we are quite addicted to a Schantz dressing to par tially immobilize the elbow This is applied as follows Two or three layers of cotton sheet wadding (such as is u ed under plaster casts) are wrapped about the arm from wrist to shoulder with the elbow at 90° These layers of cotton are then compressed by bandaging with a muslin bandage Two or more layers of sheet wadding are then applied over the first layers and the e are in turn compres ed with muslin bandage Such a dres ing tends to prevent oozing by the uniform pre sure which it exerts over the entire arm and it restricts motion both by pressure and by its bulk This dressing is allowed to remain for ten days If the fixation has been accurate and firm no form of splint is applied The forearm is hung in a sling at 90° and the patient is urged to u e the elbow gently as much as he can without pain When the fixation has not been quite firm and accurate apposition of the fragments has not been possible to at tain the elbow is immobilized at 90° with a cast which is allowed to remain for four weeks When it is removed the forearm is hung in a sling and gentle motion is begun as soon as it can be done without discom fort

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31

Fractures and Dislocations Involving Elbow Joint

FREDERICK M SMITH, M D

ANATOMY

The elbow joint is constructed for active use and mobility Stability with rare exceptions is of less importance than is motion for a useful elbow When the surgeon is confronted with the problem of treating a badly injured elbow the restoration of normal anatomy, though of great importance is not necessarily the most important desideratum of treatment A perfect looking elbow in which the x ray films show excellent anatomic alignment may be almost completely stiff and useless owing to either too prolonged immobilization or too strenuous treatment Even in a patient who has to perform no skilled movements an elbow that will not flex beyond 120° may be a serious handicap It will prevent such every day duties as getting the hand to the mouth buttoning a coat tying a necktie doing the hair and a number of other simple but important things If stiffness is to be expected following an injury, it is better for many individuals to have flexion rather than extension A stiff knee in proper position makes for a very useful leg and the lack of motion is not too severe a handicap But in the elbow as in all other joints of the upper extremity, mobility is of prime importance It is therefore often good judgment in treating elbow injuries to strive for as much function in this joint as is obtainable by any justifiable means even if this course entails some sacrifice in restoration of anatomy and x ray criteria

Everyone attempting to treat fractures or dislocations should be familiar with the anatomy of the elbow joint in both the adult and the growing child The majority of anatomic textbooks stress the adult anatomy rather than that of the growing child Elbow injuries are of far more frequent occurrence in children than in adults hence accurate knowledge of the anatomy in the child is quite important

The normal anatomy of the adult elbow can be found in any textbook of anatomy or in any fracture textbook It is a hinge joint the forearm flexing on the arm to an average angle of approximately 30° and extending *to a straight angle of 180° Some* individuals cannot flex to quite 30° if they are very muscular, but most people should be able to extend to 180° Rotation takes place between the upper end of the radius and the humerus and between the head of the radius and the ulna

The synovial membrane of the joint attaches just outside the cartilaginous articular surfaces of each of these bones This makes a surprisingly large joint cavity The collateral ligaments on either side of the joint and the orbicular (annular) ligament which holds the head of the radius in contact with the lesser sigmoid notch of the

ulna and with the capitellum of the humerus are, from the standpoint of joint stability, the ligaments of importance in treatment The anterior and posterior portions of the ligaments forming the capsule of the joint are thin, pliable, and loosely attached in order to allow free flexion and extension Lying upon and attached to the anterior capsule of the joint is the brachialis anticus muscle. [This close relationship between capsule and muscle is correlated with the frequent occurrence of myositis ossificans in this region when the anterior capsule is torn in association with elbow fractures.—Ed] In addition to inserting into the capsule this muscle also inserts low down on the front of the coronoid process of the ulna. The tip of the ulna is intra-articular in position.

GENERAL TREATMENT PROBLEMS

Displacement of fragments occurs and may persist because of: first, the original force causing the injury; second, muscle pull may, over a period of minutes or hours, complete or even increase the original displacement; third, faulty attempts at reduction may add to the original, or change one type of displacement to another; fourth, ineffective immobilization of the fragments after reduction may allow continued muscle pull to re-displace them. One is always faced with this problem of constant muscle pull, and should keep in mind the muscle or group of muscles attached to each fragment in order to reason best (1) how to facilitate reduction by relaxing the muscles that interfere with reduction, (2) how to use muscles, where possible, to help maintain reduction, and, above all else (3) how to avoid recurrence of displacement due to their pull.

The lower end of the humerus is a weak anatomic structure. This is due to its change in shape from the tubular shaft to the thinner condylar region and to the hollowed-out areas occupied by the antecubital and olecranon fossae respectively The thin expanded condylar portion predisposes to easy posterior displacement of the lower fragment in supracondylar fractures and also to difficulty in maintaining anatomic position after reduction Overcoming and maintaining correction of the all too frequently overlooked rotary displacement that often complicates posterior displacement is one of the difficulties frequently encountered The reason for immobilization in a position of acute flexion after reduction of these fractures is to utilize the action of the tensed triceps muscle to hold the fragments tightly pressed together.

The lower articular surface of the humerus is tilted forward at an angle of approximately 30° with the shaft. This is true in children as well as in adults This forward angulation should be restored as far as possible in reducing supracondylar fractures, since, theoretically at least, limitation of elbow flexion may otherwise be the result This lower articular surface, composed of the trochlear process and capitellum, has the same form in children as in adults, although by x-ray differences exist owing to variation in ossification in the former

Fig. 740 shows anteroposterior and lateral x-ray pictures of "normal" elbows and demonstrates the differences and progressive changes from the young child to the adult. Owing to the number of epiphyses at the elbow and to the variation of these at different ages and in different individuals of the same age, it is always best to take x-ray pictures of *both* elbows in children in order to have a comparison for the injured side rather than to rely upon memory to guide one in diagnosing certain fractures or displacements It will help to rule out some suspected fractures, but, more important, it will allow recognition of such injuries as displacement of the medial epicondylar epiphysis into the elbow joint in some cases of dislocation of both bones on the humerus Failure to recognize such a condition is too prevalent, and is due largely to taking

x rays of the injured elbow only the displaced epicondylar epiphysis is mistaken for a secondary ossification center in the trochlea

In children under ten years of age injury to an epiphyseal plate with or without displacement (even with perfect anatomic reduction in the former) may go on to show disturbance in growth sometimes as late as four to five years after the original injury Although this probability is not great (5 to 10 per cent of cases followed over a period of many years by clinical and yearly x ray examinations) one never knows which case may show it Consequently a wise surgeon will explain the situation to the parents of the child and warn them of the possibility of later growth disturbance in every epiphyseal injury with or without displacement In the event of subsequent growth disturbance he may thus have saved himself much unfair criticism to the effect that the elbow might have been all right had the bones been set properly Furthermore if growth disturbance does occur and the deformity becomes marked it may be necessary to perform operative correction This is very disturbing if the parents have not been warned of the possibility

The head of the radius and the tip of the coronoid process of the ulna are entirely intracapsular and without soft part attachments Fractures of these parts with separation and displacement are therefore difficult to reduce may result in a loose body within the joint if unreduced and if reduced may end in deformity in healing or fibrous union owing to the lack of blood supply in the displaced fragment

The medial epicondyle of the humerus or its epiphysis is completely extra-articular when it is broken The flexor muscles tend to displace it downward and if a dislocation of the radius and ulna has taken place on the humerus at the same time the pull of the muscles on the epicondyle or its epiphysis may cause it to curl into the joint through the torn capsule

The close proximity of the ulnar nerve to this epicondyle as it passes immediately behind it leads to frequent pressure on or stretching of the nerve during or following fracture and subsequent ulnar palsy or paralysis This possibility should always be kept in mind

Every surgeon should be familiar with the normal visible and palpable bony landmarks at the elbow Of these the most useful is the bony triangle (roughly isosceles) formed by the two epicondyles of the humerus as a base and the tip of the olecranon as the apex when the elbow is held at 90° With the elbow held in 180° extension these three landmarks are in the same straight line Deviations from these normals are a guide in the diagnosis of specific deformity after fracture or dislocation but cannot be relied upon completely for decision as to the proper form of treatment for the individual lesion Good anteroposterior and lateral x rays of the injured elbow (and in children *both* elbows) are imperative

In diacondylar Y or T fractures or in fracture of a single condyle there may be a forward tilting of the outer condylar fragment which if allowed to remain will change the axis of the capitellum as compared to the trochlea in their relation to the shaft of the humerus This change in axis of one condyle as compared with the other may interfere with perfect and full hinge motion of the forearm bones on the humerus and should therefore be corrected One must attempt to make the axes of the condyles coincide in treating this type of injury

A fracture running into the joint even if undisplaced (the capsule being intact) results in a hemarthrosis If the bleeding is marked in amount the joint capsule becomes distended and very painful and motion may become greatly limited by pain within a very few hours Aspiration of the elbow joint in such cases and under proper precautions will give almost complete relief from pain and restoration of motion range

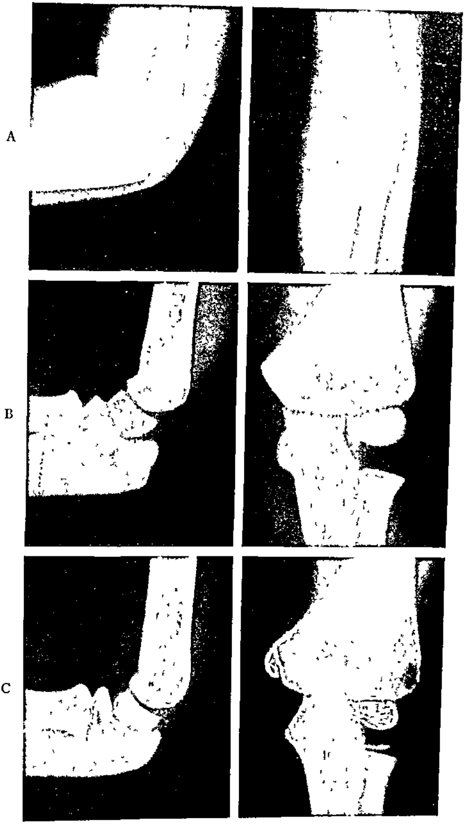

Fig. 740

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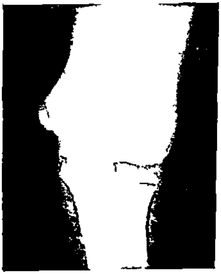

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FIG 740 Lateral (*left*) and anteroposterior (*right*) x ray views of normal elbows showing changes in epiphyseal ossification centers at following ages (A) 2½ years (B) 5 years (C) 7 years (D) 9 years (E) 10 years (F) 13 years (anteroposterior only)

If the joint has been disrupted and the ligaments torn by either a dislocation or a displaced fracture, there is of course no closed cavity left, and no tense hemarthrosis can occur since the blood leaks out into the surrounding soft tissues

With fracture or dislocation the damage done is unfortunately not confined to the bones or the joint. The surrounding soft parts often suffer far more serious immediate injury as well as subsequent inflammatory reaction due to hemorrhage, cellular infiltration, etc. In any elbow dislocation the collateral ligaments of the joint are always torn to a certain extent. The anterior and posterior ligamentous capsule may be torn as well. In addition, displacements may be accompanied by tearing or laceration of the brachialis anticus muscle or partial avulsion of the flexor group of muscles from the medial epicondyle. Ulnar-nerve injury as described above may be present.

In any fractures through the lower extremity of the humerus we may see similar damage to these muscles when the fragments are badly displaced. In some supracondylar fractures the lower end of the upper fragment of the humerus is forced not only through the brachialis anticus muscle, but through its overlying fascia, and its sharp edge becomes caught in the under surface of the skin Early ecchymosis (within an hour or two) just above the antecubital fossa is an indication that this has happened Still further, this bone may actually be compounded through the skin and become badly contaminated with dirt or bits of clothing. With wide displacement, much may happen to such structures as the brachial artery and veins and the radial, median, and ulnar nerves.

In such injuries to the joint capsule and muscles, much hemorrhage occurs and the muscles and ligaments become infiltrated with blood. This in turn sets up an inflammatory reaction characterized by cellular infiltration and edema, and the swelling often becomes so great that the venous and lymphatic circulation are seriously impeded. If there is marked hemorrhage beneath and around the brachialis anticus muscle, the brachial artery may be compressed sufficiently to stop or diminish the radial pulse This condition if left untreated may very well give rise to Volkmann's ischemic paralysis and contracture Barring for the moment any such major catastrophes, even the lesser degrees of soft-part damage may lead to thickening of the ligaments or muscles by the organization of hemorrhage and exudation, with subsequent fibrous-tissue and even bone formation in their substance (myositis ossificans). This, if permanent, decreases their pliability and elasticity and causes contractures, and motion in the joint may be greatly limited or completely abolished. To prevent and to minimize these pathologic changes is therefore a particularly important part of the problem in the treatment of elbow injuries

Injury to the large vessels, such as the brachial artery and veins, can be caused by the original displacement of the bony fragments, by motion at the fracture site during transportation of the patient to the hospital if proper protective emergency splinting is not used, by rough or overhasty manipulative reduction, or their circulation obstructed by immobilization in the acutely flexed position without first obtaining reduction, and by the use of tight circular plaster-of-paris casings or other splints held by constricting bandages. The lymphatic drainage of the part is fully as important as the venous circulation and is hindered by the same mechanism. Important in improving any form of circulatory embarrassment are: (1) Accurate and early anatomic reduction of the fracture done gently under anesthesia, (2) moderate elevation of the injured part, (3) constant low heat, (4) very gentle sedative massage in adults, but *not* in children, (5) early active motion within pain limits where possible, and (6) the avoidance of encircling plaster cases and

constricting bandages It is unwise to wait until the swelling has subsided before at tempting reduction By the time this has occurred (and it may take from a week to ten days), organization of the inflammatory exudate has been established, rendering the surrounding soft parts indurated and inelastic and making it difficult if not impossible to accomplish a successful reduction A severe elbow fracture is a real emergency, much more so than acute appendicitis, and *no time should be lost in bringing about reduction as quickly as possible*

If there is marked swelling of the injured elbow or impairment in volume or loss of the radial pulse at the wrist as compared with the uninjured arm, this is cause for real concern, and every justifiable means should be employed to correct the discrepancy in the pulse *immediately* in order to prevent Volkmann's ischemia This will be discussed under the treatment of supracondylar fractures

The ulnar, median, and posterior interosseus nerves also should be investigated for signs of damage before any treatment is instituted in serious elbow injuries or dislocations Numbness, hypesthesia, pain, or hyperesthesia should be sought for over the *sensory distribution of each of these nerves* in the hand and fingers first by questioning the patient, and second by testing out sensation to pinprick in the several distributions compared with the opposite hand (Fig 741) Motor function of each nerve should also be tested and compared with the opposite hand as to completeness and strength With the ulnar nerve this is best done by testing abduction and adduction of the fingers (interossei muscles), the median nerve is best tested by comparing flexion of the thumb, index, and middle finger and opponens action of the thumb, the posterior interosseous nerve is best tested by having the patient attempt to fully extend the fingers at the metacarpophalangeal joints Extension of the middle and distal interphalangeal joints is accomplished by the action of the ulnar-nerve innervated lumbrical muscles Nerve impairment must be taken into account, since it is extremely important to recognize such a lesion before embarking on a form of treatment that may later have to be changed when it is discovered that nerve damage is present

There is a tremendous difference in the effect of prolonged immobilization on the tissues of children and adults The former

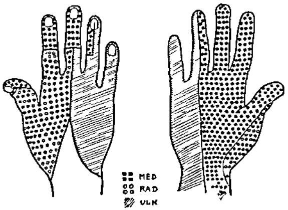


FIG 741 Distribution of skin sensation in hand and fingers according to median, ulnar, and radial nerves

show a remarkable tendency to complete recovery of joint motion after prolonged immobilization *In adults this is unfortunately not so* A week or two extra of splint wearing will not harm a child, but the same extra period in an adult may make the *difference between* complete joint function and limited function

The diagnosis of *sprain* in a child s elbow should be made only with mental reservations A true sprain in a child s elbow is a rarity The majority of so-called sprains, when good x ray films fail to show a fracture, are in reality injuries to one or more of the epiphyseal cartilages Careful clinical examination will usually make this evident In any event, it is wise to assume that the injury is epiphyseal and not ligamentous, since the former injury calls for immobilization in splints to give adequate protection against further damage which might result

in subsequent growth disturbance. If, after four or five days, tenderness to pressure localized over the epiphyseal cartilage has disappeared, it is safe to call the lesion a sprain and to remove the splint. However, should this tenderness persist for ten days to two weeks it is fair to assume that more than a sprain has occurred and the splints must be kept on for safety until this localized tenderness has disappeared. If epiphyseal trauma is passed off lightly as a sprain because of negative x-rays, and subsequent growth disturbance occurs, the situation becomes quite embarrassing.

FIRST-AID TREATMENT IN ELBOW INJURIES

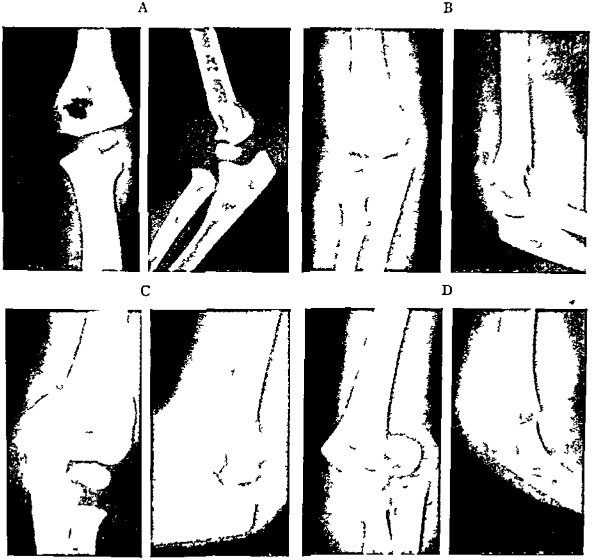
Whether the injury be a dislocation, a simple fracture, or a compound fracture, the primary purpose of immediate first-aid treatment is to prevent or minimize additional damage to the affected elbow while the patient is being transported and until he has received x-ray examination and is ready for definitive treatment.

Application of either sling or protective splint should be done without moving the patient's arm or elbow any more than absolutely necessary. Having the patient lean forward or to one side will allow the arm to swing far enough away from the body to permit application of a splint and bandage with minimal trauma. If the patient is unable to sit or stand, slight traction downward on the forearm will steady the injured elbow while the emergency splint is bandaged in place. [The Murray-Jones arm splint with fixed traction is the most desirable form of emergency splinting If this, or its improvised equivalent, cannot be used, straight board splints or their equivalents should extend from the axilla to beyond the fingers. Both the splints and the extremity should be well padded. The application should be made while firm traction is being exercised, and tight bandaging should be avoided. See Chapter 22.—Ed]

A complete and detailed diagnosis is not essential at this stage and frequently cannot be made without x-ray examination Should the surgeon be able to examine the patient within *five to ten minutes after the* injury and should he find no fracture but an obvious simple dislocation at the elbow, he may be able to reduce it on the spot with ease by simple traction without anesthesia. Local tissue shock renders the part anesthetic for from 15 to 30 minutes until swelling and muscle spasm begin to set in Consequently, athletic injuries can often be reduced immediately on the field by the team doctor with less trauma than would be necessary after taking the patient to a hospital. Such immediate reduction, however, should not rule out the advisability of subsequent x-ray examination If such reduction is done, *it should be adequately protected* and the patient transported for x-ray examination, and given further treatment as indicated Obvious fractures should be splinted for transportation and no attempt made to reduce them until x-ray examination has been obtained

Should there be any question of a compound fracture (and this should be suspected if there is any bleeding at all from the region of the injured elbow) the skin wound should be immediately covered with a sterile dressing, the elbow protected by emergency splinting, and the patient transported to a hospital without delay. Skin wounds communicating with an elbow fracture are particularly serious, and no cleansing or débridement should be done except in an operating room under strict aseptic precautions. It should not be done at the site of injury or in a doctor's office. A few hours' delay in treating a compound fracture properly may result in serious infection with subsequent loss of elbow function or even amputation to save the patient's life.

Hemorrhage from a compound fracture, if of major proportions, should call for immediate application of a tourniquet. A word of caution is here in order. Any tour-



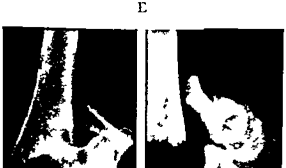


FIG 742 Anteroposterior and lateral x ray views illustrating different types of supracondylar fractures of humerus and different degrees of displacement (A) no displacement (B) loss of normal volar tilt of lower extremity of humerus (C) moderate posterior and medial displacement of distal fragment but showing no rotation of distal fragment on proximal one (D) marked posteromedial displacement and rotation of distal fragment on proximal (E) very marked posterior and medial displacement plus comminution (This patient showed posterior interosseous nerve palsy when examined ten minutes after injury)

niquet applied to the upper arm should be applied over circumferential padding (preferably one inch in thickness) in order not to cause damage to the underlying vessels and nerve trunks, one hour is the maximum time that such an improvised tourniquet *may be safely kept in place, it must be* tight enough to obliterate the arterial pulse below it. [See Chapter 22 for discussion of use of tourniquet.—Ed.]

FIG 743 *Lateral x-ray views illustrating rotation of lower humeral* fragment upon proximal following closed reduction of a supracondylar fracture and immobilization in posterior molded plaster splint (*left*). (Note so-called "fishtail" appearance of lower end of proximal fragment, which means that view of proximal fragment is more of an anteroposterior one than lateral.)
(*Right*) Same case with rotation corrected after overhead skeletal traction and suspension by Kirschner wire through upper ulna.

TREATMENT OF SPECIFIC FRACTURES

Supracondylar Fractures of Humerus in Children

This is the commonest fracture seen in the region of the elbow in children and may be the most serious. Fig. 742 shows the various types of displacement in this fracture.

PATHOLOGIC ANATOMY OF IMPORT IN TREATMENT

Displacement in supracondylar fractures begins with any loss of the normal forward *tilt of the lower fragment* When there is complete disengagement, there is very *likely to be some displacement of the lower* fragment laterally and, less often, medially.

Very rarely the distal fragment is displaced anteriorly rather than posteriorly. [While this is exceptional, it has considerable significance. Soft-part damage to anterior capsule and brachialis anticus is nil or minimal in these cases, and the brachial vessels and median nerve are not compressed or distorted over the lower end of the upper fragment. Therefore myositis ossificans, Volkmann's ischemia, and capsular contractures are not to be feared in this type of displacement —Ed]

Rotary displacement also occurs in most

instances the distal fragment being rotated internally on the proximal Consequently *its correction is often not accomplished by* the reduction It should be corrected or deformity may result If present it is usually quite easy to recognize on good lateral films The lower humeral fragment and elbow joint will appear in true lateral projection on the film while the lower end of the shaft of the humerus appears almost or quite in anteroposterior projection This gives the so called fishtail appearance to the lower end of the upper fragment and means rotation of one fragment on the other (Fig 743) Post reduction lateral films will *of course tell whether or not rotation has* been corrected Persistent rotary displacement may lead to loss of the normal carrying angle or to a reverse carrying angle (cubitus varus) the so called gunstock deformity

The brachial artery (and its accompanying veins) and the median nerve being deep to the fascia overlying the forearm and lower biceps muscle is pulled backward with a markedly displaced lower humeral fragment angulating sharply over the lower edge of the upper fragment It may be actually kinked on itself This relationship must be remembered when reduction is attempted and is one of the reasons why reduction should not be delayed merely because of soft part swelling

Among the soft tissue structures commonly injured in a displaced supracondylar fracture is the brachialis anticus muscle It may be extensively lacerated with marked infiltration by extravasated blood The hemorrhage *if extensive and if confined* beneath the deep fascia may actually shut off the return venous circulation and subsequently the arterial circulation particularly with acute flexion of the elbow (Jones position) and bring about the dreaded complication of Volkmann s ischemic paralysis with contracture of the forearm and hand

[While this is theoretically so it is actually not the effective factor in the vast majority of cases of Volkmann s contracture *The common factor toward which* treatment must be directed is the backward angulation and stretching of the brachial vessels over the lower end of the proximal fragment with resultant obliteration of their lumens by direct compression and intense vascular spasm It is this potential threat which makes the prompt reduction of bony deformity so important —Ed]

It is of paramount importance *never* to use the Jones position of supination and acute flexion of the elbow with the idea of reducing a badly displaced supracondylar *fracture Doing so may increase the kink in* the brachial artery or cause it to be caught between the fragments and irreparably damaged *The Jones position should be used only for maintenance of the reduction after it has been effected* and then only to a degree that does not impede the arterial circulation as tested by comparing the volume and force of the radial pulse with that of the uninjured arm No one should reduce a supracondylar fracture without first testing out the sensory and motor function of the median ulnar and posterior interosseous nerves

TREATMENT OF SUPRACONDYLAR (TRANSCONDYLAR OR DIACONDYLAR) FRACTURES

The best way to overcome or relieve circulatory embarrassment is to bring about reduction of the fracture This reduction should be carried out *as soon as possible* and *not* delayed until after the swelling had gone down

Reduction When there is no displacement or only a slight loss (10 to 15°) of the normal forward angulation of the lower end of the humerus as seen on lateral x ray view no reduction is necessary It is best however to partially flex the elbow to 50 or 60° if swelling and pain do not prevent and to immobilize it in a posterior molded splint and sling If swelling and pain do not per

mit this amount of flexion, it may be necessary to immobilize it in less flexion—i e., at 70 to 80°. Two or three days later, if swelling has diminished, flexion may be increased.

Immobilization. A posterior molded splint is the most satisfactory one for immobilization of these fractures The acute flexion of the elbow maintains the reduction. The advantage and safety of the molded splint as compared with circular plaster casings lie in the ease with which it, or a portion of the bandage holding it, can be removed to allow inspection of the injured elbow and treatment of swelling or bleb formation. To be effective it must extend from just below the posterior axillary fold to just proximal to the metacarpal heads. If it extends only to the wrist, the ulnar head or weight of the hand rubbing on the distal edge may cause discomfort and a pressure sore (Fig. 744) or pronation of the forearm can take place. Patients up to the age of five or six years, unless very obese, usually take a two-inch width of plaster. The remainder take a plaster three inches in width, unless they happen to be extremely large or obese adults.

In preparing the plaster splint so that no rough or sharp edges will dig or rub the skin after hardening it is advisable to use a strip of Canton flannel approximately one inch wider and longer than the expected size of the finished splint. This is laid on a board fuzzy surface down and the rubbed wet plaster splint laid on top of it. The overlapping margins and ends of the flannel are then brought over the edge of the plaster and rubbed enough to make them stick. The wet splint is then bandaged to the arm firmly and evenly while the part is held in the reduced position by an assistant. The position should be maintained until the plaster has "set." Care should be used to avoid the formation of sharp ridges or folds in the plaster, which may cause pressure areas. When the plaster has hardened, the original bandage should be cut down and replaced by a fresh bandage. Failure to do this may result in the original bandage later

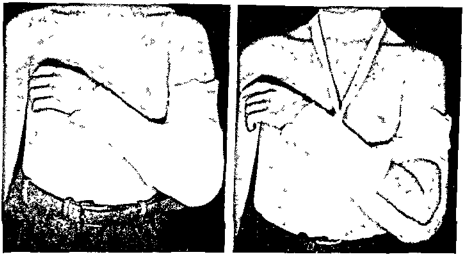


FIG. 744. (*Left*) A posterior molded plaster-of-paris splint bandaged in place. (This splint should extend more distally than is shown in photograph, i e, to metacarpophalangeal joints, in order to support hand and thus prevent a pressure area at ulnar head or base of hand)

FIG. 745. (*Right*) Same splint as in Fig. 744, but illustrating method of applying a figure-of-eight bandage to maintain desired amount of flexion in splint and yet avoid any constriction in front of elbow.

cutting into the skin since its dampness makes it apt to shrink

In rebandaging the splint it is advisable to avoid the antecubital area If the splint is bandaged first to the brachial region then to the forearm it will not readily slip In order to maintain flexion and to prevent the splint from cracking and hinging at the elbow a figure of eight is made across the front of the elbow but not in contact with the antecubital surface This figure of eight is best made after the plaster splint is hard otherwise the gauze may form ridges in the soft plaster (Fig 745)

If the patient is ambulatory he should be fitted with a muslin sling in order to support the weight of the splinted extremity This will not only afford him additional protection but also will add greatly to his comfort During the time the splint is worn exercise of the fingers and of the shoulder should be encouraged A sling will allow him to exercise the elbow in flexion after the splint has been discarded When he is doing this well it will be safe to allow him to take the arm out of the sling half a dozen times a day for the practice of extension exercises The splint should be worn for from three to four weeks and the sling for an additional two weeks

A neck halter may be used in place of the sling but this does not allow as much freedom for exercise as does the sling

Should the patient be suffering considerable pain with marked limitation of joint motion he should be examined for possible hemarthrosis recognized by the finding of a distinct tender bulge in the triangle formed by the head of the radius the lateral epicondyle of the humerus and the tip of the olecranon These three landmarks are readily palpated If it is felt that hemarthrosis is tense enough to be causing most of the pain aspiration of the elbow joint should be carried out

Technic of Aspiration of Elbow Joint The elbow region is thoroughly cleaned with green soap and water and alcohol and then painted with 3½ per cent iodine solution It is draped with sterile towels and rested on a small pillow by the patient s side A point equidistant from the radial head the lateral epicondyle and the tip of the olecranon is chosen for the site of aspiration (Fig 746) A hypodermic skin wheal is made at this point with 1 per cent novocaine With a No 11 Bard Parker blade a one eighth inch incision is made through skin only in the center of this wheal A small intravenous needle (No 20) is then

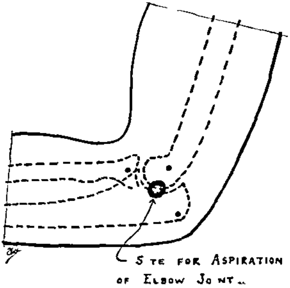
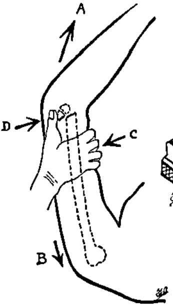


FIG 746 Proper site for introduction of needle when aspirating a hemarthrosis of elbow joint

used to infiltrate the deeper tissues down to the joint capsule with novocaine solution The purpose of the incision and of using a separate needle for infiltration of the deeper tissue is to minimize the chance of carrying skin organisms into the joint which might result from pushing a large bore needle through the skin

When the novocaine infiltration is completed a somewhat larger needle (No 17 or 18) on a syringe is inserted into the joint care being taken to keep the axis of the needle as nearly perpendicular to the skin surface as possible This allows the point of the needle to enter the distended joint

capsule between the capitellum, radial head, and sigmoid fossa of the ulna. As soon as the needle enters the joint cavity, blood may be seen to gush into the barrel of the syringe If the hemarthrosis is quite tense, the pressure may even force the plunger of the syringe outward Anywhere from 5 to 20 cc. of blood may thus be removed, particularly if the supracondylar region is compressed anteroposteriorly during aspiration.



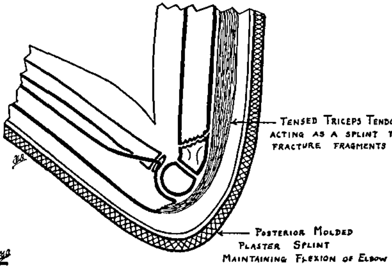


FIG. 747. (*Left*) Technic of manual reduction for a displaced supracondylar fracture of elbow while traction and counter-traction are maintained.

FIG. 748. (*Right*) Action of triceps tendon acting as a direct splint on lower fragment of humerus following reduction of a supracondylar fracture and flexion of elbow.

The needle is then withdrawn and the aspiration site covered with a sterile dressing.

Very often pain will completely disappear after aspiration and active motion range will be greatly increased. It is then much easier to immobilize the fracture in a position of more acute flexion.

When the axis of the lower fragment is in line with the axis of the shaft of the humerus, its forward inclination being largely lost, but there is no actual posterior or rotary displacement, reduction is best accomplished by flexing the elbow slowly but forcibly and immobilizing it in a posterior molded splint and sling. This is best done under an anesthetic.

When there is a backward tilt to the lower fragment, or greater displacement, an anesthetic (usually general) is necessary in order to accomplish reduction This is carried out by downward traction on the partially flexed and supinated forearm against counter-traction in the opposite direction on the upper humerus. If overriding of the fragments has been present, traction and counter-traction will overcome this with the muscles relaxed by flexion under anesthesia The next step is to overcome any lateral displacement or rotation of the fragments, which can be done by thumb pressure in the indicated direction on the lower fragment while traction is continued, care being taken to line up the axis of the forearm on the humerus as compared to the normal side.

Next, the lower fragment must be well engaged and made to lock itself on the lower end of the upper fragment. This can now

usually be accomplished by forward traction on the forearm accompanied by thumb pressure in a forward direction on the distal fragment while at the same time applying a backward (posterior) pressure on the lower anterior shaft of the humerus (Fig 747) Should the two fragments not engage with this procedure it may be necessary first to hyperextend the distal fragment by hyperextension of the elbow coincident with constant downward traction on the forearm Thumb pressure forward on the distal fragment during this hyperextension may facilitate engagement

Once the fragments are engaged completely then the elbow is flexed to maintain the reduction *but not before* Flexion of the elbow after reduction causes the tensed triceps tendon to act as a posterior splint which prevents backward slipping of the lower fragment (Fig 748) This arm is then immobilized in a posterior molded splint as described above care being taken not to impair the radial pulse either by too acute flexion or by any constricting bandage It is also important to rebandage these posterior molded splints once they have hardened and in doing so to avoid any constricting portions of bandage in the antecubital fossa

The correction of rotary displacement should be checked clinically before any splint is applied This is best done during acute flexion of the elbow If the lower humeral fragment is internally rotated on the upper the forearm will deviate to the medial side of the humerus if externally rotated the forearm will deviate to the lateral side of the humerus After application of the splint the position of the fragments should be checked by post reduction films If rotary displacement is found to persist or to have recurred a second reduction should be attempted

Following supracondylar fractures most elbows even if reduced early, may continue to swell for the first 24 hours due to hemorrhage and exudation Any constriction will obstruct the venous and lymphatic return circulation increasing swelling and edema This may lead to pain and to blister formation which may greatly complicate the program of treatment It is a wise rule to admit to the hospital for overnight or longer any child with a supracondylar fracture where marked swelling is present or where it has been necessary to perform a difficult reduction and to keep the elbow and forearm well elevated The radial pulse and the temperature color sensation and motion of the fingers can be checked frequently Any changes in these should be viewed with alarm and proper measures should be instituted immediately These consist of (1) Higher elevation (by suspension if necessary) to bring the elbow on a higher horizontal plane than the axilla and the hand higher than the elbow in order to improve gravity drainage of the veins and lymphatics (2) elimination of any constricting loops of bandage which may have become tight owing to increased swelling beneath them (3) lessening of the amount of acute flexion (4) constant low heat (5) skeletal traction and suspension with the Kirschner wire through the olecranon (see below) and as a last resort (6) operative slitting of the deep fascia to decompress the anterior forearm compartment [This latter procedure is practically never necessary if the Kirschner wire suspension method described below is instituted when the more conservative measures outlined above fail to promptly relieve diminution in the radial pulse pallor coldness and numbness in the fingers or loss of voluntary finger motion

Hospital admission after reduction is not always feasible When this is the case it is wise to instruct the parents to watch for these symptoms and to report their appearance promptly Many a Volkmann's paralysis could have been avoided by such simple precautions —Ed]

BLEB FORMATION PREVENTION AND TREATMENT

When bleb formation occurs in the ante

cubital fossa, it is an indication that the skin circulation has become partially impaired either by increased swelling or by a portion of the bandage causing constriction. Should blebs be found, immediate treatment must be instituted to prevent their increase and also to protect them from infection Cut away any constricting layers of bandage, decrease the amount of acute flexion at the elbow sufficiently to release pressure on the skin in this area, cleanse the affected skin gently but thoroughly with alcohol, dry carefully, and powder with a mild antiseptic such as stearate of zinc or powdered boric acid, apply a well-powdered single or double layer of plain sterile gauze in the antecubital fossa to prevent maceration of the apposed surfaces of skin of the forearm and arm. If the blebs are very large, it is wise to empty them by aspiration under aseptic precautions and cover them with sterile dressings. Prevention of bleb formation is important and is best accomplished by permitting no constriction by bandage. To prevent maceration of the apposed skin from perspiration keep the skin cleaned and powdered as described above even though no blebs are present.

Mention is made of the use of circular adhesive strapping or of circular plaster casing for immobilizing elbows following reduction of supracondylar fractures only to be condemned. These two methods of immobilization have led to many cases of Volkmann's ischemia and contracture. It is impossible for anyone to observe the degree of swelling at the elbow beneath a circular plaster casing extending from the upper arm to the wrist or hand Any excess swelling is prevented from expanding by such a casing and causes a vicious circle by collapsing and eventually completely obstructing the return venous circulation In the author's opinion there is no excuse whatsoever for the use of a circular plaster-of-paris casing in immobilizing a reduced supracondylar fracture of the elbow. If it is impossible to maintain reduction by holding the elbow in flexion with a posterior molded plaster-of-paris splint, then some method such as overhead traction by means of a Kirschner wire through the olecranon should be used

SKELETAL TRACTION

There is a small group (10 to 15 per cent) of supracondylar fractures that are particularly serious In these cases it is not only possible to effect and maintain a reduction by overhead traction through a Kirschner wire inserted through the olecranon, but the method offers one of the safest means of so doing and minimizes or eliminates the risk of Volkmann's ischemia. There are four types of cases in which the author believes this method to be definitely indicated: (1) Where it is impossible to obtain reduction by any conservative means, (2) where it is possible to obtain reduction, but impossible to maintain the position of the fragments in acute flexion without compromising the radial pulse, (3) where there is extreme swelling, partial circulatory embarrassment, or an impending Volkmann's ischemia, and (4) where there are additional fractures in the same extremity, or the supracondylar fracture is compounded, or where nerve palsies are already present.

The advantages and the reasons for the success of the Kirschner wire overhead traction are manifold: (1) It gives effective reduction by skeletal traction with body weight acting as counter-traction (2) It does not require the Jones' position of supination and acute flexion to maintain reduction (3) It keeps the injured part well elevated, permitting gravity to facilitate the venous and lymphatic return circulation which rapidly reduces swelling at the elbow. (4) It requires no constricting circular bandages which impede circulation. (5) It is practically painless, an item of extreme importance in children. (6) It allows early active elbow motion. (7) It keeps the patient in bed under close obser-

vation during a particularly critical period of treatment

The introduction of the Kirschner wire should be performed with the child under general anesthesia and under strict aseptic precautions It should be inserted from the medial toward the lateral side in order to lessen the chances of injuring the ulnar nerve Following preparation of the skin with iodine and alcohol and draping with sterile towels a tiny skin incision about one eighth inch long is made to avoid driving the wire through the skin in order to minimize introduction of skin organisms into the deeper tissues The wire is then placed inside a large bore needle (No 14) used as a cannula to push the soft parts away from the site of introduction into the bone This site should be at least one inch distal to the tip of the olecranon in order to avoid injuring the epiphyseal cartilage The Kirschner wire is then drilled through the bone and the skin on the lateral side incised when the point of the wire presents

After sealing off the skin wounds with sterile cotton or gauze dressings applying and tightening the yoke the arm is then suspended as in Fig 749 Swathe A is used to suspend the forearm swathe B may be used if backward pressure is required on the proximal fragment of the humerus but is not always necessary Approximately six to eight pounds traction is required on the Kirschner wire If it is necessary to correct rotation of the distal fragment of the humerus this can be done by changing the axis of the sling supporting the forearm in its horizontal plane If after 24 hours or less x ray or fluoroscopic check shows the length to have been regained but posterior or lateral displacement of the distal fragment to have persisted this may be corrected easily by manipulation under a few whiffs of nitrous-oxide anesthesia Once satisfactory position is obtained the traction weight may be reduced to approximately five pounds or less if sufficient to maintain the reduction The traction is left on for from 10 to 14 days (depending upon the amount of visible callus shown on x ray films) Once callus is sufficient the traction and wire may be removed (by this time swelling at the elbow has disappeared) and the elbow may be immobilized in flexion by a posterior molded plaster-of paris splint

TIME OF IMMOBILIZATION

This depends upon the amount of the original displacement In those with little

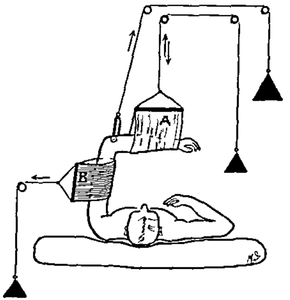


Fig 749 Method of employing over head skeletal traction and suspension by means of Kirschner wire through ulna in badly displaced or complicated supra condylar fractures of humerus (A) Swathe to support forearm (B) Swathe with traction applied to shaft of humerus if an additional posterior pull is required on this upper fragment

or no displacement a splint for from 10 to 14 days followed by a sling for another week is usually sufficient Where there has been considerable displacement originally the splint should be kept on approximately three weeks Where displacement has been marked and soft tissue damage considerable four weeks splinting is advisable Splinting for longer than this time is unwise

AFTER-TREATMENT

All patients should be seen daily or oftener if necessary during the first week after injury with a view to rebandaging the splint or lessening flexion, should swelling persist or increase. If the patient is not in the hospital, the parents must be advised specifically to notify the surgeon if severe pain, such as to prevent sleep, persists, or if the fingers feel cold or appear pale or cyanotic. Under no circumstances should a narcotic be given for pain unless the surgeon is certain that there is no threat of Volkmann's ischemia. In case of doubt, it may be advisable to admit the patient to a hospital for closer observation, consultation, or more radical treatment.

Active finger and thumb and shoulder exercises should be encouraged from the start. The surgeon must take the time to actually demonstrate to the child and to its parents exactly how to close and open the fist, to abduct and adduct the fingers, and to appose the fingertips. These exercises should be carried out half a dozen times each at hourly intervals until the child no longer has any difficulty in moving the fingers freely.

Active elbow motion, under the direct guidance and encouragement of the surgeon, may be started at the end of a week in most cases, and even earlier in the less severe ones. It is necessary to sit down with the patient and gain his confidence and cooperation Remove the bandage holding the splint, being careful to support the splint yourself, or have the patient do so, to prevent pain or fright by sudden slipping. It usually is not very difficult to get him to flex and extend the elbow actively through a small range, once he realizes you are not planning to hurt him. This can be gradually increased every two or three days When the splint is discarded, hot soaks three to four times a day, active elbow exercises in the sling, and mild active use are further encouraged. The sling rarely needs to be worn for more than seven to ten days after discarding the splint.

No other form of physiotherapy is indicated *Massage and passive motion* are potentially harmful following elbow injuries in children Passive motion is too apt to set up a protective mechanism in the child, with consequent muscle spasm, pain and increase in local circulatory stagnation, and exudation into the tissues about the joint "Pump-handle" manipulations are taboo at any time, and can be considered only as harmful Active use of the elbow, well within pain limits, is the most physiologic and the best method of regaining elbow function This may be initiated by gently resisted or gently guided motion, but under no circumstances must fear or apprehension be aroused in the child. The child should be encouraged early to carry on his usual activities, using the arm and hand for dressing, eating, writing, playing, etc Weight-carrying to increase elbow extension is often tried, but this also makes the child conscious of his injury, prolongs disability, and often causes protective muscle spasm such as may occur with passive exercise It is not advisable

Should function be unduly limited at the end of seven or eight weeks, it is often helpful to tie the patient's uninjured arm inside his shirt, thereby compelling him to use the "bad" elbow. This latter procedure usually works better than any amount of nagging on the part of the parents [This is much more effective than attempting to bandage up the good arm outside the clothing The child then will, and does, manage to get the good hand and arm free for use. If, however, when he is dressed in the morning, the good hand and arm are included in a swathe applied beneath the underclothing, it becomes necessary for him to undress in order to make use of the extremity.—Ed]

The frequency of fibrosis or of myositis ossificans in the brachialis anticus and in the anterior joint capsule as a complication of supracondylar fracture in children is in-

creased by anything which leads to the persistence of local circulatory stagnation in these tissues Muscle spasm due to pain or protective muscle splinting of the part due to apprehension are prime factors in this Passive motion massage the carrying of heavy weights and undue forcing of active motion are all examples of mechanisms producing such spasm

OPERATIVE TREATMENT

Open reduction in supracondylar fractures in children should be avoided if possible In compound fractures it is of course necessary (see Chapter 22) Adequate debridement of the wound irrigation from the depths outward with normal saline solution and reduction of the fracture should be followed preferably by the Kirschner wire traction method previously described to facilitate dressing of the wound Soft parts interposed between the fragments preventing reduction and maintenance of reduction by any closed method and old unreduced fractures are the only other conditions in which open reduction is advisable

TREATMENT OF SUPRACONDYLAR FRACTURES WITH ANTERIOR DISPLACEMENT

Anterior displacement of the distal fragment in a supracondylar fracture of the humerus is infrequent Closed reduction is carried out by manual traction and counter traction under general anesthesia Pressure directed posteriorly is exerted on the distal fragment in order to engage this with the proximal fragment In order to maintain the reduction it may be necessary to immobilize the elbow in a posterior molded plaster splint *not in acute flexion* but in complete extension This is not necessary in all cases however as the flexed position will hold the reduction perfectly in some and is a more comfortable position for the patient The decision as to the flexion or extension position for immobilization must be decided upon clinical and fluoroscopic check up after reduction has been effected

[The completely extended position should require considerable justification If adequately reduced most of these cases tend to hold with the elbow flexed to a little less or a little more than a right angle Kirschner wire overhead traction as described above will adequately hold those which tend to re displace Marked deformity does not embarrass the brachial vessels as is the case in posterior displacements The placing of pads in the antecubital fossa to force the lower fragment back is not advisable —Ed]

The after treatment in respect to duration of splinting the use of active motion etc is identical with that following reduction of supracondylar fractures with posterior displacement

COMPLICATIONS

1 Myositis Ossificans If myositis ossificans develops in the brachialis muscle in the course of treatment and elbow motion is definitely limited because of this it may be difficult to persuade the parents that judicious neglect is the best form of treatment As stated above instituting active use of the part within pain limits will do much to decrease the tendency to ossification in the brachialis anticus muscle It will also be effective in dissipating the ossification itself By the end of a year most of the patients showing myositis ossificans will have regained full motion and use on this regime There is a tendency for the process once started to increase over a period of from six to nine months and then to regress Operation to remove the ossification during the early period is very unwise and is usually followed by much more extensive ossification than existed before operation This is very likely to lead to permanent impairment of elbow function If there is still considerable limitation of elbow flexion with myositis ossificans at the end of a year it may be advisable to operatively remove the bone formation with or without capsulotomy to get adequate extension [See Chapter 22 —Ed]

2. Volkmann's Ischemic Palsy and Contracture. This is by far the most serious and most dreaded complication of supracondylar fractures It is secondary to circulatory obstruction Too acute flexion at the elbow (Jones' position) for immobilization, inadequate reduction of the fracture, tight bandages, splints, circular plaster casings or "figure-of-eight" adhesive dressings and excessive hemorrhage beneath the deep fascia are all described as factors in its etiology. It may also follow injury to the brachial artery, such as a tear from a sharp bone fragment or irritation of the vascular wall causing arterial spasm This complication is sometimes seen when no bandages, splints, or acute flexion position have been employed.

The resultant deformity is due to fibrosis of the flexor and extensor muscles in the forearm which in turn causes a clawhand. An extremity so affected is almost totally useless. The metacarpophalangeal joints are extended, the interphalangeal joints are flexed. The wrist may be partially flexed and is usually pronated On extending the wrist the metacarpophalangeal joints flex and the interphalangeal joints extend, on flexion of the wrist these finger joints move into the original deformity described The radial, ulnar, and median nerves may become secondarily involved in Volkmann's paralysis and add to the deformity and disability The condition, however, must be differentiated from primary nerve palsies. In addition to the absence of a clean-cut neurologic picture in Volkmann's, the cicatricial contracture involving the muscles and tendons does not yield under anesthesia, and in paralytic contractures due to primary nerve palsies it does yield

Prophylaxis against the occurrence of Volkmann's ischemia and contracture is really the important phase of treatment. Once the paralysis is complete, the course is irreversible and subsequent treatment is purely for the purpose of lessening the resultant deformity and disability. An ischemia from any combination of the causes cited above may be well established within a very few hours

Prophylactic Treatment

1. Adequate anatomic reduction of fracture.
2. Reasonable allowance for subsequent swelling in applying splints and bandages Frequent inspection with adjustment when indicated
3. Avoidance of such acute flexion (Jones' position) of elbow in maintaining reduction that the radial pulse is diminished in volume to even the slightest degree.
4. Elevation of injured extremity.
5. Skeletal traction and overhead suspension by Kirschner wire in cases exhibiting diminution of radial pulse volume (Fig 749)
6. Frequent careful check of volume of radial pulse, and of temperature and color of hand and fingers. Pulse must be brought back to full volume and kept so before fear of ischemia can be dispelled. According to Scudder, "Inspection of all bandages, splints, and forced positions of flexion must be made religiously and frequently" [See Chapter 22 for further details —Ed.]

Treatment After Onset, but Before Paralysis Is Complete Relieve pressure on the brachial artery and veins: (1) By loosening or removing the splints or bandages at the onset of secondary pain or swelling, (2) by lessening the amount of flexion at the elbow, (3) by operation (multiple incisions) to release the excessive hematoma beneath the deep fascia as a last resort if everything else has failed

Any additional procedures mentioned under Prophylactic Treatment, above, and not included in the above three.

Treatment After Paralysis Is Complete. If seen within the first two or three weeks the treatment should be based on the prevention of contractures. This is done by splinting the wrist and fingers in extension.

The splint must be removed three or four times daily for exercises (active and passive) to keep the joints from stiffening. Hot soaks and massage to the flexor and extensor muscles in the forearm are also essential. It may be necessary to carry on with this treatment for six months to a year or longer. Some restoration of function may be obtained and less deformity result.

If seen *after* contractures are present and no improvement can be obtained from the above-described program of splinting, soaks, massage and exercises, then some operative procedure is necessary to lessen the deformity and to improve function. Such procedures include shortening of the forearm bones, arthrodesis of the wrist, and transplantation of the origin of the flexor muscles from the humerus to a position on the ulna in the forearm. If there is secondary nerve involvement, a neurolysis may be necessary. [For further details see Chapter 22. Ed.]

PROGNOSIS

The prognosis of supracondylar fractures is in general good. The milder forms result in no anatomic deformity and regain full function and use. If the forward inclination of the humeral articular surface is not adequately restored, there may be some permanent loss of elbow flexion (5 to 20° depending on the amount of incomplete restoration) with a similar gain in elbow extension—i.e., hyperextension beyond 180°. A slight loss of flexion rarely causes any handicap. If flexion is limited by 30° or more there will be some disability.

The chief residual anatomic deformity in about 30 per cent of patients is some loss of the carrying angle at the elbow. This often goes unnoticed by the patient or his parents and causes no disability whatsoever. Should the loss of the carrying angle be complete or should the deformity be of the reverse carrying angle or so-called "gun stock" type, it may be quite noticeable. The arm has an awkward appearance on certain motions, but this rarely causes any disability. It is needless to state that such residual deformity should be observed yearly or oftener if necessary, because if the lower humeral epiphysis has been injured at the time of the fracture, a progressive growth disturbance may result. It is only by following such cases over a period of time (years) that one can tell whether or not the deformity is on the increase. Should the deformity become sufficiently marked, particularly in a female, it may be advisable for cosmetic reasons to correct it by a supracondylar wedge osteotomy.

SEPARATION OF LOWER EPIPHYSIS OF HUMERUS

This diagnosis, while often apparent on the x-ray film, must at times be made on the basis of the clinical examination alone when there is no visible displacement. Tenderness corresponds in these latter cases to the anatomic location of the epiphyseal line. If the lower humeral epiphysis is seen to be displaced on the x-ray film as compared to the uninjured elbow, the diagnosis is obvious.

Reduction is carried out under general anesthesia and the epiphyseal fragment is pushed forward by thumb pressure, followed by flexion of the elbow. The elbow should then be immobilized as in supracondylar fractures. If the diagnosis is a clinical one without x-ray evidence of displacement, the patient may have just as much pain, swelling and disability as the case with displacement. There is often an associated hemarthrosis of the elbow joint owing to the fact that the lower humeral epiphysis is purely intra-articular. This, if marked, may cause the greater proportion of the patient's symptoms. Aspiration of the elbow joint under strict aseptic precautions will give remarkable relief of pain. (See p. 881.) The elbow is then immobilized as above. If the epiphyseal plate has been disturbed, localized tenderness along the epiphyseal

line persists for at least ten days or two weeks.

SPRAIN OF ELBOW IN CHILDREN

A sprain of a child's elbow joint is an exceedingly rare condition, as stated under General Considerations. The majority of so-called "sprains" are in reality epiphyseal traumata Follow-up examinations and x-ray films after such injury often show growth disturbances in the lower end of the humerus, even though there had been no demonstrable displacement of this epiphysis at the time of the original injury, and often none apparent for two to three years after injury. Consequently, one should advise the patient's parents that growth disturbance may occur in these cases and recommend periodic check on this score. Otherwise cause for criticism may exist if and when growth disturbance does occur, and, in addition, undue deformity may develop before corrective measures are instituted.

The period of immobilization in these epiphyseal separations with or without actual displacement should be from 10 to 14 days. The treatment otherwise is the same as for supracondylar fractures. Failure to treat these injuries as fractures by plaster splint immobilization—handling them, instead, as sprains by sling only—may increase the chances of subsequent growth disturbance due to the added trauma during the acute phase of the epiphyseal disturbance If the injury has been purely a sprain, the tenderness will disappear in from four to five days, and the splint may then be removed and a sling continued for another week if necessary. [See Chapter 22 for a discussion of epiphyseal traumata in general.—Ed.]

Diacondylar "Y" Fracture of Lower Extremity of Humerus

The diacondylar "Y" or "T" fracture of the lower extremity of the humerus, though not nearly so common as supracondylar fractures in children, is nevertheless the most commonly found fracture involving the lower humerus in adults. It is usually sustained by direct violence and often compounded An associated fracture of the radial head or olecranon may be present The condyles are often separated widely from each other and from the lower end of the humeral shaft because of the pull of the muscle attachments on each epicondyle Furthermore, there is usually marked soft-part damage, with swelling and vascular disturbance

These are serious fractures because they are difficult to reduce and maintain reduced by any closed method of treatment with the assurance of subsequent good function in the elbow joint. No closed method of treatment can assure a combined good esthetic and functional result. If we strive to restore the normal architecture of the joint surfaces, we frequently sacrifice function, and vice versa, in these fractures If good anatomy is obtained by closed reduction, it is possible to maintain this only by prolonged immobilization, which in turn allows fibrosis and thickening in the joint capsule, possibly actual bone formation in the capsule, and not infrequently a complete bony ankylosis. Older methods of treatment by prolonged immobilization did just this, and resulted so frequently in bony ankylosis that it was deemed wise by the men employing it to immobilize the elbow in supination at 90° of flexion as the best position for function if the elbow became stiff. As has been pointed out before, it is usually desirable to obtain as much function as possible rather than to strive for perfect appearance. The present-day methods of treatment are based on regaining function in these diacondylar "Y" or "T" fractures.

TREATMENT

There are several closed methods of treatment, none of which is completely perfect for all these fractures There is practically no fixation dressing or splint competent to maintain any sort of reduction unless it is

combined with traction The Magnuson felt-cuff traction on the upper forearm is quite effective (Fig 750) The patient lies on a hard mattress with the shaft of the humerus resting on the latter Skin traction is applied to the forearm which is flexed to 90° The felt cuff with 10 to 15 pounds of weight exerts a downward force through days the motion helping to mold the fragments into a position that will allow further increased function and helping to decrease the hemorrhage and swelling in the capsule and muscles surrounding the joint

If the Magnuson felt traction is not sufficiently effective to reduce the fragments overhead skeletal traction may be used by

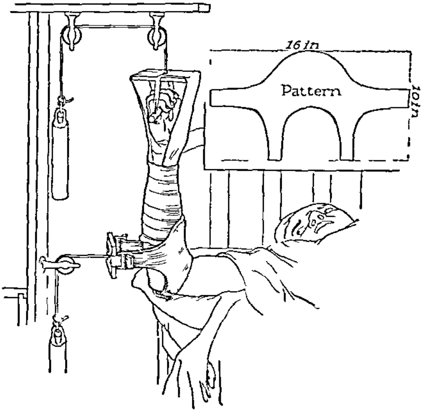


Fig 750 Method of applying traction in Y fracture of humerus Inset shows method of cutting felt to fit snugly around lower end of humerus (Courtesy Magnuson P B Fractures Philadelphia Lippincott)

the collateral ligaments regaining length Manipulative molding of the fragments under general anesthesia is of great assistance in overcoming the spread of the condyles This traction must be kept on for two to three weeks after which the elbow is immobilized in a molded plaster splint for another three weeks Mild active motion is begun at three weeks after the injury As a matter of fact some active motion may be allowed in this traction after four or five means of the Kirschner wire inserted through the olecranon as described for supracondylar fractures previously Either method will usually give a fairly satisfactory functional result [If it can be used the skeletal traction is the more effective method —Ed]

Skin traction with the elbow at 90° in the Jones traction splint may be used but it necessitates the patient's carrying a rather heavy piece of apparatus and also elimi

nates the use of early exercises and active motion

Wilson and Cochrane advocate closed reduction similar to that used in supracondylar fractures—i e, by traction and manipulation under anesthesia, plus molding of the condyles together by local thumb and finger pressure and immobilization of the elbow in acute flexion in the Jones' position with a halter around the patient's neck This allows motion in flexion, and as this increases the halter is gradually lengthened, allowing more extension. When the elbow can be extended to 90°, the halter is then changed to a sling and further active extension encouraged This takes about three to four weeks With this method the weight of the arm acting by gravity acts as traction, and the triceps tendon serves the purpose of a posterior splint

Operative Treatment. Open reduction has many advocates and many critics In the first place, open reduction of diacondylar "Y" and "T" fractures should not be attempted by surgeons without experience, or in hospitals where the proper facilities, equipment, and personnel for open reduction are not of the best In the second place, it is not always feasible to perform open reductions, because of the age of the patient or other physical or economic hindrances, or because of the very marked comminution of the fragments which may make it mechanically impossible to apply firm internal fixation There are many cases, however, where far better functional as well as anatomic results can be obtained if open reduction is done with internal fixation, followed by early active motion in traction and suspension and assisted by heat, massage, and elevation If facilities for and experience in performing open reductions are up to proper standards, and operation has been decided upon as the best method of treatment for the immediate case, it should be done early (i e, within the first few days or a week) in order not to waste time or needlessly traumatize the fracture site and surrounding soft parts by repeated unsuccessful attempts at closed reduction (Fig 751) [If operative fixation is to be employed it is unquestionably best employed as the primary method of treatment within the first 8 to 12 hours Each 12 hour period thereafter, and each attempt at manipulative reduction, takes from its chances of optimum success —Ed]

A B

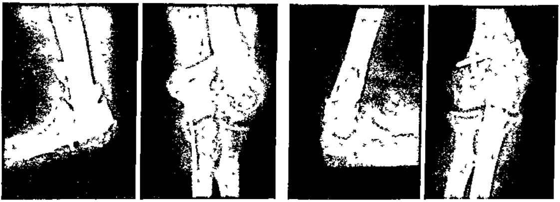


FIG 751 Lateral and anteroposterior x-ray views of a dicondylar fracture of humerus suitable for operative treatment (A) before operation, (B) after operation

Operative Method Exposure for open reduction can be obtained by two lateral incisions or by a U-shaped incision. The fracture site should be exposed on either side of the triceps tendon or by dividing

this tendon and later resuturing it It is often necessary to free and retract the ulnar nerve to prevent contusing it If the fracture extends into the articular surface any small loose fragments within the joint should be removed The main fragments should then be re assembled in anatomic position and each condyle fastened rigidly to the other and to the shaft preferably by stainless steel or vitallium screws or by screws and plates Some surgeons use nails bone pegs or wire fixation but screws will usually fasten the fragments more firmly and maintain their position more adequately when early active motion is started

Following operation the arm should be elevated by suspension in traction to facilitate reduction of soft tissue swelling and to allow early *active* motion If internal fixation is adequate no splint should be used as this will counteract the purpose of the operation—i e allowing early active motion Heat and massage should be given daily Under no circumstances should these elbow injuries be given forced *passive* motion or manipulations when treated by either closed or open methods In from two to three weeks the patient can usually be allowed up wearing a sling (provided fixation has been rigid) and then should be made to practice *active* flexion extension and rotation exercises every hour or two Heat by thermolite or hot soaks and massage should be continued Occupational therapy especially loom work to increase flexion and extension at the elbow may be advantageous after the first month following operation [See Chapter 22 for details as to exercise massage etc —Ed]

Disability time in these fractures treated by one of the advocated closed methods usually runs from four to six months treated by open reduction the time is often shorter—from three to four months

PROGNOSIS

The prognosis is far better now that function rather than perfect anatomy is considered the important goal in these diacondylar Y and T fractures It is also better in young to middle aged adults than in elderly persons due to quicker and more complete recovery from soft part damage and circulatory disturbance and the less serious effects of the necessary immobilization

Fractures of Lateral or Medial Condyle of Humerus into Joint

A fracture of either the lateral or the medial condyle of the humerus alone is uncommon but may result in serious loss of the elbow joint function In the first place the fracture line communicates with the joint and adhesions if immobilized too long may limit motion In the second place the fragment is usually displaced by tilting or rotation or both due to the pull of the flexor muscles on the medial side or the extensors on the lateral side Any change in the axis of the separated fragment will interfere with perfect hinge motion in the joint and may greatly limit flexion and extension

TREATMENT

The problem here is to regain as much function as possible It can be done by two methods The conservative method requires traction on the forearm flexed at 90° by means of the Magnuson felt cuff (Fig 750) or by means of a Kirschner wire through the olecranon with overhead suspension Early active motion must be started within two or three days assisted by such physiotherapy as massage heat and elevation and the range of motion gradually increased as pain and swelling subside It is surprising how excellent the functional result may be if such treatment is carried out On the other hand the functional result is much more apt to be poor if such an elbow is immobilized in splints or a plaster casing for a period of four weeks

The more radical method of open reduction should be carried out in younger

adults, who have to earn a livelihood, if the proper facilities are available and no other real contraindication to operation presents itself The purpose of open reduction is of course to allow anatomic reposition of the fragment plus firm internal fixation in order that early active motion can be begun without fear of displacing the fragment, and to make it unnecessary to use

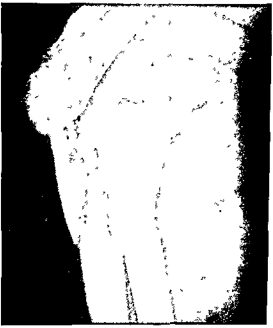


FIG 752 Lateral x-ray view of elbow illustrating a badly comminuted fracture of "truck-swipe" or "side-swipe" variety.

splints or plaster casings Depending upon the location of the fracture line and shape of the fragment, internal fixation may be effected by the use of several screws or a small steel plate An occasional wire loop is necessary if screws alone are inadequate or if only a single screw can be used Nails are often used, but these rarely hold the fragments as rigidly as a screw, because they tend to loosen more readily with decalcification. These fractures are often difficult to fix internally even in expert hands, and one should not attempt it without proper training, experience, and equipment.

PROGNOSIS

The prognosis is approximately the same as with diacondylar "Y" or "T" fractures, perhaps somewhat better in general

"Side-swipe" or "Truck-swipe" Fractures of Lower Extremity of Humerus

The term "side-swipe" or "truck-swipe" is applied to certain very severe fractures around the elbow sustained by the driver of an automobile whose elbow while resting on the windowsill of the car has been struck by a portion of the overhanging body of a truck he has tried to pass too closely on a narrow road or by an object into which he has skidded It is the most serious elbow fracture we see, because the blow is direct and is delivered at high speed The elbow and lower humerus are driven backward against the window frame and literally shattered. The humerus fracture is almost always compounded as well as badly comminuted, the compounding frequently involving the upper ends of the radius and ulna and the elbow-joint cavity (Fig 752) The joint becomes completely disrupted, soft-part damage is excessive, involving nerves and vessels as well as muscles, and there may be actually a loss of substance (skin, muscle, portions of vessels and nerve trunks, or even bone fragments). The injury, of course, may be of any degree and may not be compounded The milder types, however, are less common

TREATMENT

The treatment depends of course on the extent of the injury The fractures which are comminuted, but not compounded, are best treated by traction and suspension, aided by gentle manipulation under anesthesia, with molding of the fragments into their best possible position for function, rather than into perfect anatomic reposition. The skeletal overhead traction is the best form. This is followed by early active motion, in order to regain a maximum of

elbow joint function Unless the fragments are few in amount and large it is inadvisable to attempt an open reduction with rigid internal fixation unless one is equipped with proper facilities for doing good bone surgery and also is well experienced in such work Conservative treatment usually gives better functional results than ill advised attempts at open reduction in these injuries

When the fracture is compounded debridement must be done but should be on the conservative side The wound should be thoroughly irrigated with quantities of normal saline solution The fragments should not as a general rule be fixed internally and the wound is best treated by packing it wide open with petrolatum gauze or suturing very very loosely By the use of overhead skeletal traction the elbow can be held in the optimum position for the fracture fragments and for change of dressings All of the patients should receive antitetanus serum For chemotherapy see Chapter 22

Should the wound become infected drainage must be made adequate by opening the wound completely if necessary and employing frequent irrigation with normal saline solution Irrigation with saline is advocated here in place of Dakin s solution or other antiseptic solutions Normal saline is the least irritating as it is a physiologic solution Dakin s solution is considered by many to cause decalcification of the bone fragments thereby lessening the chances of bony union Furthermore Dakin s solution in a joint is felt to be definitely irritating The elbow is very likely to become ankylosed if infection has involved the joint and the position of immobilization should then be in whatever degree of flexion or extension is optimum for the particular patient s occupation or daily needs

AFTER TREATMENT

This depends upon the extent of the original injury loss of substance nerve injuries and supervening infection Operative procedures should be avoided after the initial debridement etc except for the necessity of establishing better drainage in infection or in carrying out sequestrectomy of dead bone fragments If the elbow joint is going to be flail it may be necessary to provide the patient with some form of brace to stabilize it and to make it easier for him to flex the elbow without using his other hand to assist it in this action

PROGNOSIS

The prognosis is serious because it may be difficult to save the extremity if gangrene

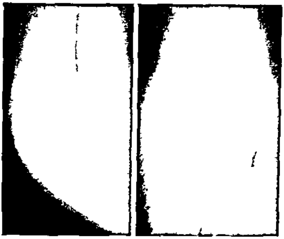


Fig 753 Lateral and anteroposterior x ray views illustrating fracture of lateral condyle of humerus in a child with downward displacement and rotation of lower fragment (which consists of capitellar epiphysis and a portion of *lateral condyle proper)*

or infection sets in and because the deformity and disability may be a big handicap from the economic standpoint in a laborer or in a man whose occupation is in the skilled trade the disability may require him to give up his job

Fractures of Lateral Condyle and Separation of Epiphysis of Capitellum in Children

These injuries though not nearly so common as supracondylar fractures in children are often more serious in nature from the

standpoint of prognosis. The fracture line runs from just above the lateral epicondyle downward and medially into the joint, separating the capitellar epiphysis with a fragment of diaphysis attached to it from the trochlea (Fig. 753). These are essentially epiphyseal separations, although the fracture line is not seen to pass along the epiphyseal plate, and they frequently lead to growth disturbance of the lower lateral aspect of the humerus The amount of diaphysis broken off which remains attached to the capitellar epiphysis varies from a thin shell to a piece as large as or slightly larger than the capitellum itself The displacement of the distal fragment varies from slight or none to complete downward, forward, and lateral displacement with rotation. Rotation of the fragment may be as great as 180°. The direct pull of the extensor muscles of the wrist, which take their origin from the lateral epicondyle, is the cause of the displacement and rotation.

Reduction not only must be done early but must be anatomically accurate, effecting direct apposition of the fragments, and must be adequately maintained if subsequent deformity is to be avoided and full function restored. Owing to the amount of displacement and rotation, it is often impossible to reduce the fracture by any closed method In addition, it may be difficult or even impossible to maintain reduction. For these reasons some surgeons routinely perform open reductions on all those badly displaced Unless accurate apposition is obtained and maintained, the blood supply to the distal fragment will not be well reestablished, and growth disturbance is very likely to take place. I personally feel that an attempt at closed reduction should be tried once, realizing the possible necessity of open reduction and warning the parents of this in advance. Repeated attempts at closed reduction are definitely harmful because they cause additional damage to an already injured epiphysis.

TREATMENT

Closed. Closed reduction when accomplished is best done by manual traction on the partially flexed forearm with the latter adducted upon the humerus in order to widen the space between the radial head and the lateral condyle of the humerus. At the same time thumb manipulation is used to correct the rotation and displacement of the distal fragment, checking the position by fluoroscopic control. Once reduced, the position is best maintained by moderately acute flexion (60 to 70°) of the elbow and immobilization in a posterior molded plaster splint. This splint should be kept on for a period of three to four weeks, very much as in the more severe supracondylar fractures. The after-treatment is also similar. Those fractures with little or no displacement of course require no reduction, but should be splinted as above for two weeks.

Operative. Open reduction may be done as a primary procedure or after failure to reduce the fracture by one attempt with the closed method However, when open reduction is to be done, it is better done early —i e , within the first two days after injury or, better still, immediately. If open reduction is performed, it is essential to fix the distal fragment internally, and this fixation should be by rigid means rather than by mere suture of the periosteal attachment. Firm internal fixation may be obtained by the use of small wire nails, metal screws, or even bone pegs If necessary, owing to the small size of the diaphysial fragment, a small wire nail may be driven actually through the epiphyseal plate without causing any appreciable harm. Theoretically it is bad to do this, but actually the damage done represents such a small area of the epiphyseal cartilage that the firm fixation obtained far outweighs any harm done. The after-treatment is the same as with the unoperated cases.

It is advised by some to remove the dis-

placed capitellum and attached diaphysial fragment rather than to attempt open reduction and fixation This may be the only logical procedure in old unreduced cases of several months duration but there seems little advantage in this procedure in fresh cases Some possibly recommend this because they have never fixed a lateral condyle fragment at operation with anything firmer than a suture and have had far from good results in such cases

End result studies in a great many clinics throughout the country show far better anatomic and functional results when these displaced lateral condyle fractures are treated by immediate open reduction and *firm* internal fixation rather than by any closed method or by removal

PROGNOSIS

This depends upon the amount of displacement the accuracy and maintenance of reduction and upon possible subsequent growth disturbance Incomplete reduction or failure to maintain reduction often leads to a broadened condylar region and some limitation of elbow motion chiefly flexion If this is considerable there will be impaired use and operative removal may be indicated Late operative removal of the fragment however rarely gives a perfect functioning elbow

A late complication resulting from growth disturbance is retardation of the growth of the lateral condyle This gives rise to an increased carrying angle (cubitus valgus) deformity Such a deformity puts the ulnar nerve on the stretch and also causes the tip of the olecranon in full elbow extension to impinge on the nerve in its groove on the posterior aspect of the medial epicondyle Repeated trauma of this type sets up a neuritis which gives rise to a palsy and eventually perhaps to complete paralysis This may occur ten or more years after the original injury The patient and his parents should be warned of the possibility, and if symptoms begin and show progression operative transference of the ulnar nerve should be carried out as described later before the paralysis becomes complete Otherwise such paralysis may be permanent and no success can be expected from the operation

SEPARATION OF EPIPHYSIS OF MEDIAL (INTERNAL) EPICONDYLE OF HUMERUS

In this type of fracture the medial epicondyle epiphysis may not actually be grossly separated but only traumatized the diagnosis being purely a clinical one On the other hand it may be slightly or widely separated from its normal attachment having been avulsed by the pull of the tendinous attachment of the wrist and finger flexors The displacement is always downward Wide displacement of this epiphysis is commonly seen in a posterior dislocation of both bones at the elbow Occasionally in such dislocations the epiphysis is actually displaced into the elbow joint through the opening made by the disruption of the medial (internal) collateral ligament and capsule and of course requires operative therapy (see below) (Fig 754)

The downward displacement per se of the medial epicondyle epiphysis is of little consequence and causes no late functional disability It reattaches in its new (displaced) position and although it may become somewhat enlarged by subsequent growth the flexor muscles attached to it are able to function just as well as before

TREATMENT

It is rarely possible to reduce this fragment completely by any closed method It is best to immobilize the elbow in moderate flexion in a posterior molded splint in order to relax the pull of the attached flexor muscles The fragment rarely reattaches itself to the medial condyle of the humerus by bony union even if completely reduced The splint should be kept on for from two to three weeks followed by a sling for one week Active motion is then allowed Pas

sive motion and massage are contraindicated

Some surgeons advise open operation and suturing of the epiphyseal fragment to the medial condyle, but in the author's opinion this is an unnecessary operation, and the late clinical and x-ray results do not show sufficient benefit to warrant its use If ulnar-nerve sensory or motor signs are associated with a displaced medial epicondyle epiphysis, it may be advisable to operate, reattach the epiphysis, and transplant the ulnar nerve from its groove behind the epiphysis to in front of it.

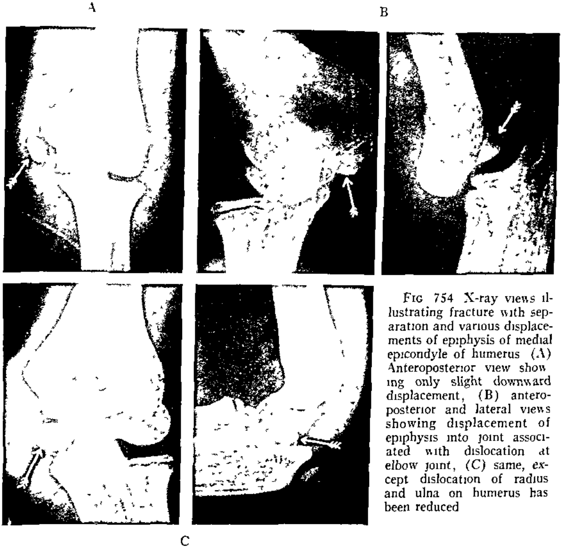


FIG 754 X-ray views illustrating fracture with separation and various displacements of epiphysis of medial epicondyle of humerus (A) Anteroposterior view showing only slight downward displacement, (B) anteroposterior and lateral views showing displacement of epiphysis into joint associated with dislocation at elbow joint, (C) same, except dislocation of radius and ulna on humerus has been reduced

The displacement of the medial epicondyle epiphysis in association with a posterior or posterolateral dislocation at the elbow joint is a condition requiring careful x-ray study, and possibly special treatment In every child suffering from a dislocation at the elbow, one should look at the x-ray films for evidence of displacement of the medial epicondyle epiphysis. Such displacement must *not* be ruled out on x-ray films of the injured elbow only Films of the uninjured elbow should be taken for comparison, because there are many epiphyses at the lower end of the humerus and there may be

multiple ossification centers in the trochlear epiphysis alone which may be confusing If there is but little displacement of the medial epicondyle epiphysis, one need not be concerned and may go ahead with reduction of the dislocation If the epiphysis is widely displaced, it is *absolutely essential* to make sure whether or not it has been drawn into the elbow joint If one can be reasonably certain that no displacement into the joint exists, he may proceed with a closed reduction of the dislocation If there is evidence of ulnar nerve damage open reduction rather than closed should be performed because the nerve may be caught within the joint and require transplantation anterior to the epicondyle which at the same time may be re sutured in its normal position (See below for operative technic)

If, after careful study and comparison of the two elbow x ray films, the epiphysis is found to be in the joint, an immediate open reduction should be performed It is almost impossible by any closed method of reduction of the dislocation or by manipulation to bring the epiphyseal fragment out of the joint The chances of success are far overshadowed by the risk of incomplete removal and still further by the greater risk of adding injury to the ulnar nerve

Technic of Operation for Removal of Medial Epicondyle Epiphysis Displaced into Elbow Joint An incision approximately 8 cm long is made along the medial supracondylar ridge of the humerus and medial aspect of the elbow joint The deep fascia is then incised vertically The epiphyseal fragment of the medial epicondyle will not be found at its normal attachment and will not be found on first exploring the elbow joint This is because it is covered by the upper part of the flexor muscles where these curl laterally into the joint through the tear in the capsule (Fig 755) This portion of inwardly curled muscle should be withdrawn from inside the joint by means of a sharp hook or toothed forceps, and suddenly the displaced epiphysis will "pop" up into full view Reduction of the dislocation should be performed at this point by traction on the forearm and manipulation into position which can be done under direct vision with the joint open The torn medial collateral ligament should

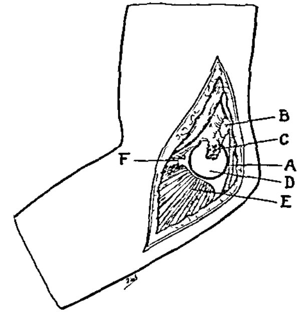


Fig 755 Sketch showing muscles attached to epiphysis of medial epicondyle curling into joint in a case where epiphysis has been displaced into joint following dislocation (A) Ulnar nerve (B) site from which medial epicondyle epiphysis has been avulsed (C) torn attachment of medial collateral ligament of elbow joint (D) medial aspect of trochlea (E) upper portion of flexor pronator group of muscles curled into joint through torn capsule and ligaments —displaced medial epicondyle epiphysis is hidden beneath this (F) torn anterior capsule and muscle

then be sutured if possible The displaced epiphysis must now be reattached to the medial condyle by a stout silk or wire (stainless steel) suture passed through a drill hole in the humerus and through the tendinous attachment of the muscles to the epicondyle, and the latter snugged up into position The wound is then closed in layers After application of a sterile dressing a posterior molded splint is applied to im

mobilize the elbow in approximately 70 to 80° of flexion.

Should the displacement of the epiphysis into the elbow joint go unrecognized either before or after reduction of the elbow dislocation, it will lead to persistence of pain, disability, and restricted elbow motion An ulnar-nerve palsy may develop because this nerve is sometimes pulled into the joint by the epiphyseal fragment These complications occur often enough to make one be on the lookout for them. When late cases are seen, operation is a necessity, but the prognosis is never so good as it is when proper treatment has been given immediately following injury, because of loss of elasticity of the tissues, extra- and intra-articular fibrosis and adhesions, and long-standing nerve involvement.

Transplantation (Transference) of Ulnar Nerve to Flexor Surface of Elbow. When there has been damage to the ulnar nerve due (1) to dislocation at the elbow, fracture and displacement of the medial epicondyle or its epiphysis, whether the result of contusion or stretching of the nerve, or (2) to compression by subsequent callus or scar-tissue formation, the ulnar nerve should be transferred from its groove on the posterior aspect of the medial epicondyle to the front of the elbow. Occasional delayed ulnar-nerve palsy follows as a result of an increased carrying angle (cubitus valgus) deformity resulting from improper treatment of or growth disturbance in fractures of the capitellum and lateral condyle of the humerus in children This may occur many years after the original injury and likewise requires transference of the ulnar nerve if the paralysis is progressive, and *always* before it becomes complete

Technic of Operation. The arm should rest on a table in external rotation An incision 10 cm long is made, starting 5 cm. above the medial epicondyle on the posteromedial aspect of the elbow and curved slightly forward below this epicondyle. The anterior flap of skin and subcutaneous tissue is dissected forward The ulnar nerve is then identified above the medial epicondyle and dissected free of its surrounding soft tissues A fibrous sheet holds the nerve in the groove and the tendinous attachment of the humeral and ulnar heads of the flexor carpi ulnaris muscle also cover it These structures must be divided by cutting down upon a grooved director, thus exposing the nerve still further. In separating the lower portion of the nerve, care should be taken to identify and save the small muscular branches coming off in this region The nerve is then lifted from its groove (dividing if necessary any adhesions, scar tissue, or callus attached to it), and then brought over the epicondyle and condyle to the anteromedial surface In this position it is anchored to subcutaneous tissue by several fine silk sutures passed through its sheath.

Even if there has been no recent dislocation, it is advisable, following an operation for transference of the nerve, to immobilize the elbow in 80 to 90° of flexion in a posterior molded splint for a week to ten days, followed by a sling for a week and with gradually increased active exercises, active use, and hot soaks

PROGNOSIS

Fracture of the medial epicondyle epiphysis with or without displacement very rarely gives any permanent functional impairment If any remains, it is usually a partial limitation (10 to 30°) of full elbow extension, which, however, causes no disability. An interesting point about these fractures is the prolonged length of time that it takes to regain full extension, frequently six months to a year being necessary. For this reason it is wise to forewarn the parents of the patient, so that they will not undertake themselves to massage or forcibly extend the elbow for the purpose of regaining this extension more rapidly

With widely displaced epiphyses a thickened medial epicondyle results as an ana-

tomic deformity This, however, is only a palpable and not a visible deformity

With a medial epicondyle epiphysis displaced into the elbow joint the prognosis is excellent if the condition is recognized and operation performed immediately If it goes unrecognized for several weeks or longer and comes to operation late, the prognosis, owing to fibrosis etc can rarely be as good as in fresh cases treated correctly from the beginning

Fracture of Medial Epicondyle of Humerus in Adults

Fractures of the medial epicondyle of the humerus in adults are exceedingly rare, and, as they do not displace into the joint are not serious If the fragment is displaced it is usually downward due to the pull of the flexor muscles This displacement in itself causes no permanent functional disability even though it be as much as 1 to 2 cm The displaced epicondyle fragment reattaches by fibrous union to the humerus or capsule of the elbow joint and causes no pain loss of joint function or weakness of flexor power in the wrist or hand The ulnar nerve function should be watched for possible palsy throughout the healing period

Treatment

Treatment of this fracture consists of partial immobilization in a posterior molded splint and sling *for ten days to two weeks* and a sling alone for a similar period Heat massage and active elbow exercises should be started at the end of a week The only reason for operating upon such a fracture would be because of an associated ulnar nerve palsy, in which case the fragment should be replaced and the ulnar nerve transplanted anterior to the medial epicondyle

Prognosis

The total disability time in this fracture should not exceed five to six weeks Partial disability lasts from three to four weeks Return of function should be complete Associated nerve lesions if recognized and treated properly should give little or no permanent trouble

Fracture of Olecranon in Adults

This is a rather common injury in adults and due most often to indirect violence and muscular action The fracture line is usually transverse and penetrates directly into the greater sigmoid cavity of the ulna at approximately its middle third or slightly more proximal There is rarely any comminution unless the fracture has resulted from a direct blow In general there are two types of olecranon fractures those *without* separation of the fragments and those *with* separation The amount of separation depends directly on the extent of the tear in the triceps expansion and periosteum If no separation is seen on lateral x ray films there is little or no tear of this triceps expansion If separation of the fragments is wide the tear of the periosteum and triceps expansion must be relatively complete

Treatment

Treatment of these fractures is based upon whether there is little or much separation of the fragments

When separation of the fragments is one quarter inch or less and does not increase beyond this with flexion of the elbow to 90°, *the treatment should be conservative* The elbow should be immobilized from the shoulder to the knuckles in a posterior molded splint and sling with the elbow at right angles and the forearm in midrotation Many advocate wearing this splint for from three to four weeks but actually it need not be kept on for more than three or four days to allow pain swelling and muscle spasm to subside Then a sling should be worn for another two weeks, during which time heat, massage, and mild active motion are carried out at frequent intervals It is important to restore elbow function as quickly and completely as possible, and this cannot be done

if the splint is kept on for four weeks. Bony union is usually solid in from six to eight weeks.

Where wide separation of the fragments has taken place and the triceps expansion and periosteum are extensively torn, there are two types of treatment. conservative and operative The conservative method requires immobilization in a posterior molded splint with the elbow in full extension for from three to five weeks An attempt may be made to approximate the fragments by manipulation and by criss-cross adhesive strapping over properly placed padding. This is not a favorable position for circulation, and the fragments may again separate in spite of the strapping which, at best, remains tightly placed for only four or five days We believe this method should be reserved for situations where it is not possible to operate, either in very elderly people or where the skin or some other condition contraindicates the operative procedure.

In the opinion of many surgeons operation should always be done in widely separated olecranon fractures, assuming that the patient can be transported to a hospital where satisfactory bone surgery can be performed The operation is not difficult, but asepsis and technic must be perfect, because this fracture communicates with the elbow joint and any postoperative infection may give a permanent disability or even ankylosis Operation is advised because of (1) marked irregularity of the joint surfaces of the fragments, which if not accurately approximated may later cause pain or limited function from the development of a traumatic arthritis, (2) loss of power of the elongated triceps action, and (3) because it is a quicker and more certain method of getting a good result (i e., a movable and strong elbow).

Technic of Operation. The open reduction is best done through a lateral incision curved medially below the olecranon, keeping well away from the ulnar nerve. After dissecting back the skin flap, the periosteum is incised along the posterior aspect of the olecranon and upper ulnar shaft and elevated to either side The material used for internal fixation is preferably metal or fascia Stainless-steel wire loops inserted through a transverse drill hole in each fragment or through the triceps insertion on the upper fragment will give good firm approximation if twisted tight while the upper fragment is held down firmly to the lower with a bone hook This type of wire causes little or no tissue reaction and is very strong The twisted end of the wire can be bent and made to lie flush with the bone beneath the periosteum so that no prominent point will remain to irritate the skin One should be careful to get good approximation of the fragments before tightening the wire to avoid a rough joint surface in the greater sigmoid cavity of the ulna The triceps expansion and periosteum should be closed with interrupted fine silk sutures Any small loose fragments of bone should be removed to avoid the risk of loose bodies in the joint Likewise all blood clots or masses of fibrin should also be removed The operation is best done immediately or, next best, within the first few days after injury If firm fixation of the fragments is obtained, active motion may be started in three or four days after operation (i e, as soon as the acute postoperative pain has subsided). (See After-care.)

Other means of fixation consist in the use of screws, nails, plates, or pins There is no one method good for all cases The principle of adequate fixation and early active motion applies to all cases regardless of what type of internal fixation is used Silk or catgut sutures used to hold the bone fragments are apt to be unsatisfactory because they fail to give sufficiently secure fixation to allow of early function

Fascia from the triceps tendon, when used after the method described by Rhombolt, makes a good type of repair which has the advantage of tending to crowd the fragments closer together whenever the triceps

muscle contracts It also obviates the use of a metallic foreign body and permits early active motion It is not so simple a procedure as fixation with a wire loop It also may allow some separation of the fragments after motion is begun and for this reason is not so satisfactory as wire fixation Its chief advantage is for fixation of comminuted fractures where it is too difficult to use wire

Technic of Fascial Repair This consists of forming a strip of triceps fascia about four inches long by one half inch wide This is split longitudinally into two equal halves, the lower insertion into the tip of the olecranon being left attached A hole one-quarter inch in diameter is then bored well into the posterior aspect of the upper end of the lower ulna fragment A similar hole is bored from either side, starting slightly distal to the first one and directed slightly upward to connect with the first hole in the depths of the bone Both strips of fascia are inserted into the first hole, and one is brought out through each side hole By traction on these strips the olecranon is pulled down into contact with the lower fragment Each strip is then carried upward and sutured both to the other and to the surrounding periosteum by interrupted silk The lateral triceps expansions and periosteum are likewise sutured where torn and the defect in the triceps fascia proximal to the olecranon is closed (Fig 756)

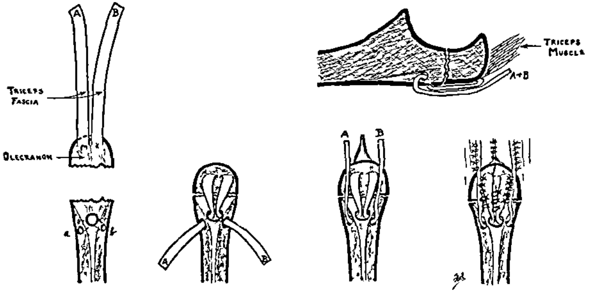


FIG 756 Rhombold s method of repairing fracture of olecranon by means of triceps fascia

Excision of Olecranon and Repair of Triceps Watson Jones advocates excision of the olecranon and repair of the triceps as an alternative method of operative repair, particularly where the olecranon fracture is high and separates a small fragment, or in elderly individuals with badly comminuted fractures He states, ' It must be recognized that the essential part of the operation is not the excision of the fragment, but the repair of the [triceps] tendon

TECHNIC The fragment of olecranon is dissected out cleanly by sharp dissection, and mattress sutures are used to fasten the triceps tendon and its expansion to the fore arm muscles and fascia on either side of the lower fragment A firmer repair may be accomplished by using a strip of fascia lata from the thigh woven through the triceps tendon and muscle and passed through a drill hole in the proximal shaft of the ulna The triceps tendon itself may be similarly employed

AFTER-CARE IN OPERATED CASES

The after-treatment where adequate fixation has been obtained with one of the above described means should consist of early active motion and exercises, heat, and massage Passive motion should be avoided A posterior splint for three or four days after operation, followed by a sling for three weeks, is sufficient immobilization in most cases The disability time for light work should not exceed six weeks In a man doing heavy work it may last from eight to ten weeks

PROGNOSIS

The prognosis in olecranon fractures with little or no separation should be good (i.e, full or nearly full return of function and strength and no noticeable deformity) provided immobilization is not prolonged and early active exercise and active use are carried out

In olecranon fractures with wide separation, the prognosis depends on what has been done to correct this If little or nothing has been done in this respect, noticeable deformity will result, with limited range of motion and with weakness in extension. The operative treatment is more apt to give a better functioning and a stronger elbow because it not only corrects the wide separation of fragments, but also allows early exercise and active use

Fracture of Olecranon and Separation of Olecranon Epiphysis in Children

This is a rare lesion in children and the olecranon fragment rarely shows any appreciable displacement If the fracture line is situated distal to the olecranon epiphysis it is frequently of the greenstick variety. One must also be careful not to confuse multiple ossification centers in the olecranon epiphysis with such a fracture

TREATMENT

Those fractures *without separation* are best treated by immobilization in a posterior molded plaster splint and sling at right-angle flexion for about two weeks, followed by sling, hot soaks three times a day, active exercise, and graduated active use Those *with displacement* are best immobilized in extension for three to four weeks and then treated as above Passive motion and massage should be avoided in the after-treatment.

One should note the difference between this and the treatment advocated for adults with widely displaced or separated olecranon fractures. Prolonged immobilization does not have the bad effect on children's tissues that it does on those of adults, and the child's tissues recover normal elasticity and function much more rapidly than do adult tissues

PROGNOSIS

This is generally good in children from the standpoint of both anatomy and function. There is rarely any residual deformity, and functional return in the elbow joint is usually full

Fracture of Coronoid Process of Ulna

This fracture may occur without other injuries, but this is rare It is seen most often in association with a posterior dislocation of both bones at the elbow joint. The displacement of the fragment is in a proximal direction due to the pull of the brachialis anticus muscle which is attached not to its tip but anteriorly at its base. The tip of the coronoid is purely intra-articular in position and may even become a loose body within the joint following reduction of the dislocation.

TREATMENT

The treatment consists of reduction of the dislocation, if present, and immobilization in a posterior molded splint and sling for three weeks with the elbow in moderately acute flexion (70 to 80°). The splint should be removed every other day for in-

spection of the swelling and for heat and massage therapy (in adults) During this three weeks care should be taken not to allow the patient to extend the elbow beyond 120° while his splint is off for fear of causing a redislocation This should be followed by sling support for a week with continued heat, massage graduated exercises, and active use The immobilization naturally has to be of longer duration than is necessary in dislocation not associated with a fracture of the coronoid process, since the fracture predisposes to easy recurrence of the dislocation If after reduction, the tip of the coronoid (i e, the intra articular portion) seems actually displaced into the joint it might be advisable to explore the joint through an anterolateral incision (see Fig 757) in order to remove the fragment Otherwise it may later cause trouble as a freely movable loose body within the joint cavity

PROGNOSIS

If the coronoid process unites it may or may not give any disability Most often there is no permanent disability, but if the union results in an elongated process there may be some loss of flexion in the elbow joint If the coronoid process fails to unite two complications may result (1) A predisposition to recurrent dislocation at the elbow, and (2) the possible creation of a loose body in the joint which may cause a traumatic arthritis due to irritation and mechanical locking, with pain and progressive limitation of function The loose body, if present, should be removed before such symptoms become marked

Fractures of Head and Neck of Radius

The head and neck of the radius are very common sites of fractures, in adults as well as in children These fractures often go unrecognized, because in the milder forms of fracture without displacement the diagnosis frequently has to be made from the clinical examination rather than by x ray As the facture line frequently cannot be seen on x ray plates the condition is often mistaken for a sprain Frequently this is to the patient s advantage because no splint is applied, and he is allowed early active motion This aids in more rapid restoration of function

A hemarthrosis accompanies all radial head fractures Though pain is slight at first, it increases with the increasing tension

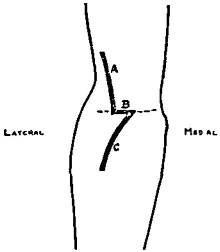


Fig 757 Z shaped incision for anterolateral approach to elbow joint This approach is imperative in removal of radial head fractures associated with elbow dislocation because of extensive anterior soft part damage and extravasation in order to allow for escape of this accumulation which predisposes to myositis ossificans in a high percentage of cases

of blood in the joint The patient may give a typical story of a fall on the hand following which he noted some pain on the outer side of the elbow in the region of the radial head Since this was not great at first, and since motion was nearly complete, he paid very little attention to it After an hour or two however pain began to increase and the elbow became stiffer i e motion decreased markedly The pain increases sometimes to a degree where the patient describes it as a sensation of throbbing and

nothing he does for it gives relief. It prevents sleep, and motion in the joint (especially flexion and extension) is so limited that more than a few degrees of either causes an increase of the pain A bulge will be found on the posterolateral aspect of the elbow in the triangle formed by the radial head, lateral epicondyle of the humerus, and tip of the olecranon This will be elastic and servative This consists in preliminary aspiration of the hemarthrosis, if excessive pain and distention of the joint capsule indicate its necessity, under strict aseptic technic Following aspiration pain will quickly disappear and the range of motion (both active and passive) in the elbow joint will immediately be greatly increased

Immobilization of the elbow should be by

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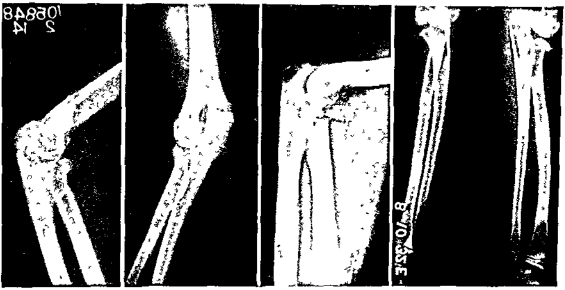


Fig. 758 X-ray views illustrating different types of fractures of head of radius: (A) without displacement or with minimal displacement, (B) with moderate displacement, (C) with marked displacement, (D) with displacement of radial-head epiphysis in a child (From the Fracture Service of The Presbyterian Hospital, New York)

fluctuant Pressure over this causes exquisite pain. The hemarthrosis here gives more symptoms than the fracture per se. For remedy of this, see under Aspiration of Elbow Joint, p 881.

TREATMENT

The principle of treatment for radial-head fractures in adults is pretty well agreed upon throughout this country and is based on the amount of displacement of the fragments (Fig. 758).

Conservative Method. (a) With a linear crack in the radial head and little or no displacement, the treatment should be conservative a posterior molded splint extending from the upper humerus to the wrist for three to five days, followed by a sling for another week Heat and massage, early *active* exercises every two or three hours, and active use within pain limits are important from the start The massage should be omitted in children

The disability time in fractures thus treated is approximately two weeks if the hemarthrosis has been aspirated, and about four weeks if not aspirated, due to prolongation of pain and spasm in the latter cases The return of function is usually complete or nearly so by this method, be-

cause prolonged immobilization which so frequently diminishes the elasticity of the surrounding soft tissues is not employed

Bohler treats these mild fractures by immobilization in a circular plaster casing for four weeks By this method the disability time is prolonged for two to three months or longer and we have seen permanent limitation of function by this method more often than with early institution of motion

Operative Method (Indications) (b) With marked displacement of the whole radial head or a fragment of it or with marked comminution the treatment of choice is operative Some surgeons say that if more than a third of the head is fractured and displaced or if the displaced fragment is from the anterior portion of the head (where it can cause greater loss of function in the joint) it or the whole head should be removed In general the consensus in this country is that the *entire* head and neck should be removed instead of merely removing the displaced fragment or fragments Another point that is generally agreed upon is that this removal should be done *early* By early is meant within the first 24 or 48 hours after the injury and *not* at the end of a week or later

[While in general it is assuredly true that removal of the radial head is best done as soon after injury as possible there is one group of cases in which the removal should be an emergency procedure done within 12 hours of injury if possible and through an anterior route rather than through the route described below This special group is comprised of those cases accompanying dislocation or subluxation of both bones backward at the elbow In these cases the radial head fragments are displaced anteriorly and there is marked swelling and tissue infiltration over the front of the elbow joint indicating coincident capsular and brachialis anticus damage If unoperated or if operated on after 24 hours and through the usual route roughly 50 per cent of these cases develop varying degrees of myositis ossificans in the brachialis anticus muscle and attached capsule with resultant disability If operated on before the lapse of 24 hours and through an anterior approach described below under operative technic the risk of such myositis is practically nil —Ed]

Technic of Operative Removal of Radial Head A 2½ inch incision is made on the lateral side of the elbow directly over the *capitellum and head and neck of* the radius The incision is deepened through the origin of the wrist extensors attached to the lateral epicondyle of the humerus These are split longitudinally to expose the joint capsule This is then opened exposing the head and neck of the radius On opening the capsule a collection of old blood and joint fluid escapes Any loose bone or cartilaginous fragments must be picked out

A thin curved elevator is then placed deep to the radial neck to afford counter pressure The neck is then divided transversely with a thin sharp osteotome about one quarter inch distal to the lower border of the head By alternately pronating and supinating the forearm as the cuts are made with the osteotome the line of resection is made circumferential This not only makes a cleaner transverse section of the neck but helps prevent splitting off the deep cortex as a sharp spike If such a spike is left it may cause irritation and limited function and may also give rise to partial regeneration of the neck and head

Following removal of the head the stumps of the neck may be treated in a variety of ways to minimize the risk of subsequent bone production Some surgeons turn in the orbicular ligament or portions of muscle to cover it others cauterize the cut end with the electrocautery or use fascia lata covering Some such method seems advisable Under no circumstances should the radial head be removed with a Gigli saw or filed smooth with a bone rasp Both these procedures increase the risk of new bone formation

When a fracture of the upper ulna accompanies a radial head fracture Magnu

son advocates not removing the latter until the ulna is firmly united, in order that the radial head may give support in the meantime and prevent angulation and shortening of the ulna This would therefore necessitate putting off excision of the radial head until after the period of increased calcification had reached its maximum and was on the decrease. This would be somewhere between nine months and a year after injury. If the ulna fracture is in the upper shaft and the fragments are angulated, it would seem more advisable to perform an open reduction on the ulna and fix it internally and rigidly with plate and screws and at the same time remove the radial head through a separate incision. The single incision advocated by Speed and Boyd is an excellent one and adequate to care for both conditions (See p. 918 and Figs 766 and 767.)

This combination of fractures is vicious, and the ulna frequently continues to angulate from constant muscle pull after closed reduction and splint immobilization This results in malunion or nonunion with marked loss of strength and function as well as deformity

AFTER-CARE

Physiotherapy in the form of heat, massage, early active motion, and immediate use are instituted as soon as the postoperative pain has subsided, and are kept up until maximum function is regained No splint is necessary following simple excision of the radial head [In the cases referred to above, with anterior displacement of the radial-head fragments associated with signs of damage to the anterior capsule and the brachialis anticus, the approach is via the incision shown in Fig 757 and described for anterior dislocation of the radial head After removal of the radial head and all loose fragments and thorough lavage of the operative area, the capsule and brachialis anticus are loosely closed, *but the deep fascia is left completely unsutured* to provide for the prompt escape of any blood ooze or inflammatory exudate The skin and subcutaneous tissues are loosely approximated and active motion is instituted as soon as the acute postoperative reaction has passed

The procedure may also be done via a transverse incision from the front of one epicondyle to the front of the other —Ed]

TREATMENT IN CHILDREN

In children, when there is no actual displacement of the radial-head epiphysis, the treatment is conservative as described above for similar fractures in adults. If the head is definitely tilted by a greenstick type of fracture in the neck of the radius, an attempt should be made to correct this by closed manipulation under general anesthesia It is often very difficult to do owing to impaction, but, by rotating the forearm under fluoroscopic control, the thumb can be used to straighten the neck as required If there has been no correction after a thorough attempt at reduction, *do not operate*, but continue as above conservatively

It is not wise to excise the radial head in children even if widely displaced, because it contains the upper epiphysis and growth disturbance will usually result which may later cause trouble at the inferior radioulnar joint If the widely displaced head cannot be replaced by closed methods, open reduction should be resorted to, and the head should be replaced if possible and sutured or otherwise fixed in position This is followed at the end of two weeks by active motion, but not by massage.

PROGNOSIS

Proper removal of the *entire* radial head *early* does not interfere with the strength of the forearm and is less apt to show late disability due to traumatic arthritis than if the separated fragment alone is removed Late removal of the radial head often leads to the formation of myositis ossificans or undue regeneration of the head. This may

cause permanent loss of considerable useful function This should therefore be done immediately or not until after a year has elapsed

The conservative treatment of the milder radial head fractures gives excellent anatomic symptomatic and functional results if the principles of early active motion physiotherapy and use are carried out as described above

TREATMENT OF SPECIFIC DISLOCATIONS AT ELBOW JOINT

General

Dislocations at any joint occur only at the expense of tears in the ligaments and capsular structures of the joint In the elbow in addition there may be laceration of the brachialis anticus muscle the close association of which with the anterior capsule has been stressed under the heading of elbow anatomy and general treatment problems The ulnar nerve is the most commonly injured nerve and may sometimes be caught within the joint at the time of the dislocation or after reduction has been accomplished With an anterior dislocation of the radial head associated with fracture and angulation of the upper ulnar shaft and tear of the orbicular ligament the radial nerve may also be injured In discussing the treatment of various elbow fractures it has been pointed out that dislocation of one or both bones at the elbow not infrequently accompanies one of these fractures As the fracture may affect the type of treatment to be carried out for the dislocation and vice versa their recognition is extremely important The e have been di cu ed under treatment of the specific fracture

Before any reduction of a dislocation is attempted it is worth while to spend several minutes testing for nerve function (motor and sensory) of the ulnar median and radial nerves as well as in checking the pulse and circulation and comparing the injured with the opposite side The existence of any nerve lesion may alter considerably the proposed plan of treatment It is most embarrassing after reduction to discover a nerve palsy and not to know whether it has been the result of the original injury or caused by too enthusiastic manipulation

Many elbow dislocations if seen within the first 10 to 15 minutes after injury and before pain swelling and muscle spasm have set in may be reduced easily by simple downward traction upon the forearm

In general after the first half hour the onset of pain swelling and muscle spasm usually makes a general anesthetic necessary or advisable

In children dislocation must be carefully differentiated from supracondylar fractures of the humerus with displacement

Dislocations of Both Bones Backward

Dislocation of the radius and ulna on the humerus is by far the commonest type of elbow dislocation in both adults and children The upper ends of the radius and ulna are displaced posteriorly on the lower extremity of the humerus and there may also be lateral or medial displacement In adults a fracture of the coronoid process of the ulna or a fracture of the radial head is often an associated lesion The medial collateral ligament is always torn allowing abnormal abduction of the forearm on the humerus In children an associated separation of the medial epicondyle epiphysis of the humerus is often seen This is sometimes displaced within the joint and if it remains between the trochlea and the olecranon following reduction of the dislocation operation is obligatory with removal of it from the joint and reattachment to the humerus

REDUCTION

Reduction of an elbow dislocation should be done as soon as possible Where the injury occurs on the athletic field and the team surgeon is immediately available and

if he finds only a simple dislocation, he may reduce it on the spot by simple manual traction in a downward direction without anesthesia. Such reduction is not only possible before pain, swelling, and muscle spasm have set in, but is advisable Following this and the application of an emergency splint, the patient should of course be sent for x-ray examination to rule out additional bony injury.

Usually, however, a patient with a posterior dislocation of both bones is not seen and x-rayed until after pain and swelling have begun. By this time it is advisable if not absolutely necessary to perform the reduction under general anesthesia, because it is easier and painless with the muscles relaxed and also because it can be done with the infliction of much less additional trauma to the bones and the soft parts.

The patient should be supine on the table under anesthesia. The forearm which is supinated is grasped just above the wrist while the elbow is kept in moderate extension (140 to 160°). Downward manual traction is then made on the forearm while counter-traction upward on the humerus by an assistant is carried out to relax the biceps muscle. If there has been lateral or medial displacement of the two forearm bones, this should be corrected by thumb pressure in the indicated direction prior to reducing the posterior displacement. When this is corrected, the traction and counter-traction are continued, and, at the same time counter-pressure on the front of the humerus is made by the palm of the hand. Each of these procedures should be slow, even, and steady—not jerky—and when muscular relaxation is complete the upper ends of the ulna and radius will slide beneath the lower articular surface of the humerus into their normal position. Following reduction it is possible to flex the elbow fully and freely.

IMMOBILIZATION

After reduction, immobilization is best carried out by the use of a posterior molded plaster-of-paris splint and sling The splint should be worn for approximately one week to ten days and the sling for an additional similar period The splint should extend from the neck of the humerus to the metacarpophalangeal joints with the elbow flexed to less than a right angle Usually 70 to 80° of elbow flexion is sufficient

AFTER-TREATMENT

The elbow should be removed from the splint three or four times daily after the first two days for lamp heat or for hot-water soaks. Care should be taken not to allow extension of the elbow to beyond 130° for at least two weeks in order to minimize the chance of redislocation. In adults gentle massage will help decrease the swelling and will also exert some sedative effect In children massage is not advised because of its tendency to predispose to the formation of myositis ossificans in the brachialis anticus muscle. Active motion within pain limits should be started within two or three days after reduction. Passive motion in my opinion is definitely harmful and contraindicated in both adults and children, as it increases pain, causes muscular spasm, and increases hemorrhage in the torn brachialis muscle.

With an associated fracture of the coronoid process, redislocation is apt to occur, because it is the tip of this coronoid that prevents the ulna from sliding posteriorly on the humerus except in forced hyperextension. Treatment after reduction has to be altered slightly to take care of this fracture. The elbow should be immobilized preferably in more acute flexion (i e , 50 to 60°) and should be kept splinted for three to four weeks Extension beyond 90 or 100° should be limited purposely for four weeks, and extension beyond 150° not allowed for six weeks. The prognosis for a perfect elbow is naturally not so good owing to the necessity for longer immobilization and also because there is an increased tendency with

coronoid fractures toward the formation of myositis ossificans which in itself may give limitation of motion

Certain other fractures are not infrequently seen associated with a posterior dislocation at the elbow The most common is a separation of the medial epicondyle epiphysis of the humerus in children which occasionally becomes displaced into the joint Fracture of the head of the radius is seen less commonly Either fracture may be serious when associated with dislocation These and nerve lesions associated with them are discussed under the treatment of each specific fracture

DISABILITY TIME

Without an associated fracture the disability time in posterior dislocations runs from two to three weeks for light work to four to five weeks for heavy work *With* an associated coronoid process fracture the disability time is roughly doubled

PROGNOSIS

In uncomplicated posterior dislocations at the elbow reduced early and treated as described the prognosis is usually excellent The most frequent sequel is slight loss of flexion and extension and deposition of calcium in the healed collateral ligaments There is as a rule no permanent disability with 10 to 15° loss of either flexion or extension With associated injuries the prognosis if these are treated properly is also good with the exception of fractures of the radial head or of the coronoid process owing to the tendency toward formation of myositis ossificans

UNREDUCED DISLOCATIONS

Old unreduced elbow dislocations are serious injuries and after two weeks frequently cannot be reduced by any closed method owing to swelling exudation and organization of blood clot and new fibrous adhesions Eliason remarks that an elbow dislocation grows old early and is usually impossible to reduce by any closed treatment after ten days to two weeks In these there are several procedures that may be tried (1) Traction and manipulation (2) sham reduction (3) arthrotomy and open reduction and (4) arthroplasty

TREATMENT

If the dislocation is not too old (i e of less than two weeks duration) an attempt at closed reduction should be tried It is carried out by prolonged steady traction on the forearm in its axis with the patient well relaxed under general anesthesia After traction has been maintained for a full five minutes the elbow should be very gradually flexed while counter traction and backward pressure on the humerus are kept up as described under reduction of fresh elbow dislocations A second attempt at traction etc may be tried if the first is unsuccessful If reduction is accomplished the elbow should be immobilized in flexion in a posterior molded splint for three to four weeks The after treatment is the same as with fresh dislocations but the return to function is much more prolonged (two to four months) and motion is frequently limited permanently owing to the thickening of the peri articular structures and to adhesions within the joint

If manipulative reduction fails in these unreduced dislocations or if the duration of the dislocation is so long that surgical judgment rules out attempting it several operative procedures may be performed None of these operations should be done however at a period when the x ray film shows marked evidence of myositis ossificans in the soft parts surrounding the joint If such ossification is seen it may be better to treat the elbow temporarily at least by the so-called sham reduction of Hugh Owen Thomas This procedure is not a reduction at all but merely flexion of the elbow to less than a right angle and holding it in this position for three weeks by a collar and cuff following which the patient

is encouraged to regain what motion he can at the false joint If no great amount of motion is recovered and disability is considerable, then an arthroplasty may be done after the period of increased ossification has ceased

If it is impossible to reduce the old dislocation and if no myositis ossificans is present, an arthrotomy and open reduction may be performed and is advisable. This applies more particularly to children than to adults because they will respond to after-treatment better In adults an arthroplasty in very old unreduced dislocations is often better.

Technic of Open Reduction (as described by Willis C. Campbell):

An incision is made over the posterolateral aspect of the arm, beginning in the midline four inches above the olecranon process and extending down to just above the tip of the olecranon, thence slightly outward over the external condyle of the humerus, the head of the radius, and continuing two inches on the forearm The edges of the incision are elevated and retracted, exposing the tendinous insertion of the triceps muscle and the posterior surface of the elbow joint.

The tendinous aponeurosis of the triceps muscle is dissected out at its proximal end and turned downward as a tongue-like flap, remaining attached to the olecranon. An incision is next made directly in the midline through the fibers of the triceps muscle down to the humerus, extending from three inches up on the shaft to the reflection of the joint capsule around the articular surfaces. All the muscular attachments over the lower end of the humerus, both anteriorly and posteriorly, are stripped free, together with the periosteum The attachments of the joint capsule around the condyles of the humerus are then separated close to the bone If dissection is carried close to the bone the ulnar nerve rarely comes into view, but may be located and detached from its bed along the groove in the internal condyle, and retracted out of danger. Often there is considerable callus formation over the posterior surface of the humerus around the olecranon fossa, from stripping up of the periosteum at the time of the original injury, this callus with the scar tissue in the olecranon fossa is thoroughly removed.

Having completely freed the lower end of the humerus and exposed the capitellum and head of the radius, the forearm is twisted with gentle pressure over the capitellum, causing the head of the radius to glide forward into the normal position If this is not readily accomplished, the soft tissues should be dissected more widely, to obviate the necessity for the use of force and consequent danger of injury to the articular surfaces After the radius is reduced, the coronoid process may be slipped forward over the trochlea and reduction completed The joint is then carried through the full range of motion. The periosteum and muscles are closed along the posterior surface of the humerus, and the fascia is sutured over the head of the radius. The aponeurosis of the triceps muscle is sutured into its normal position or at a slightly lower level [See Figs. 759, 760, 761, 762.]

AFTER-TREATMENT

Immobilization of the elbow at 90° in a posterior molded splint is carried out for eight to ten days. Following this and healing of the operative wound the splint should be removed three times daily for baking (thermolite) or hot soaks, massage, and active elbow exercises. At the end of two and a half to three weeks the splint should be used only at night, the arm being carried in a sling during the day The splint should be worn at night only for another six to eight weeks to prevent or minimize contracture formation The exercises should be continued for four to six months or until the maximum strength and function has been regained.

ARTHROPLASTY AT ELBOW JOINT

As mentioned above in adults with an unreduced dislocation of two months' duration or longer, an open reduction rarely gives a satisfactory result. In these cases it is preferable to perform an arthroplasty It is not in the scope of this chapter to describe in detail the technic of arthroplasty, as various methods are described elsewhere.

In general, the elbow joint is exposed along the posterolateral aspect very much as for open reduction. The soft tissues are

reflected subperiosteally from the lower three inches of the humerus on all sides and likewise from the olecranon and head and neck of the radius The lower extremity of the humerus and upper extremities of the radius and ulna are resected transversely to their axes by a sharp osteotome removing approximately one and one half inches from the humerus and ulna and somewhat less from the radius The bone ends are then smoothed off with a rasp At this point one must decide whether he wishes to cover the bone ends with a fascia lata envelope in order to create a false joint cavity or not Although some surgeons with wide experience in arthroplasty operations do not do this it would seem to be a desirable procedure to prevent bony ankylosis following the operation After closure of the wound the elbow is immobilized in traction and suspension in order to keep the newly created false joint surfaces apart [For further discussion of arthroplasty see Chapter 15]

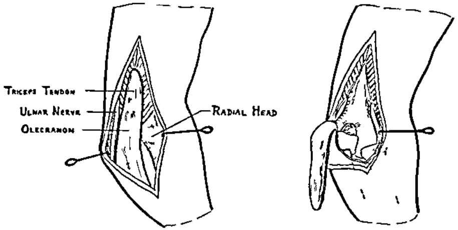


Fig 759 (*Left*) Operation for old unreduced posterior dislocation of elbow Exposure of triceps aponeurosis and isolation of ulnar nerve (After Campbell) (See also Figs 760 761 762)

Fig 760 (*Right*) Triceps tendon dissected free and reflected distally Incision through muscle fibers to humerus Muscle stripped subperiosteally from shaft and both condyles of humerus completely mobilizing this portion of bone (After Campbell)

After treatment The elbow should be kept in traction and suspension for from two to three weeks After ten days early active motion in traction is started and encouraged every hour Heat and massage are also important at this time After removal from traction the patient should be allowed up in a posterior molded splint and sling with the elbow at right angles Physiotherapy and active exercises must be carried out now every two hours religiously by removing the splint temporarily for these The splint need not be worn in the daytime after the fifth or sixth week but should be worn at night until three months after operation It is necessary to continue the exercises and active use for six months or longer until maximum function has been regained

PROGNOSIS

The prognosis in unreduced elbow dislocations is directly proportional to their duration If they come early enough to reduce by closed methods without force the prognosis is relatively good About the best that one can expect is 70 to 80 per cent return of function If the dislocation requires either open reduction or arthroplasty,

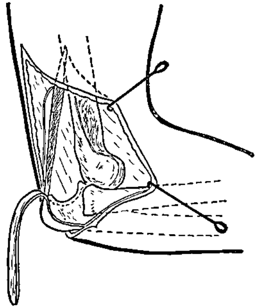
the results are never so good. A 50 to 60 per cent return of function is the most that can be expected. Many with dislocations of long standing where fibrosis in and around the joint is extensive and dense do not obtain better than 30 to 40 per cent return of function. The prognosis as to disability would depend on three things: (1) The patient's occupation, (2) his cooperation in securing the return of function, and (3) his age. Children are much more apt to recover function and begin using the elbow than are adults. The important thing to remember is that these are serious conditions and that as few days as possible should be lost after unsuccessful attempts at closed reduction before the patient is subjected to open reduction.

Forward Dislocation of Both Bones

Forward dislocation of the ulna and radius on the lower extremity of the humerus is a very rare lesion and is usually associated with an oblique fracture of the olecranon.

TREATMENT

If no fracture is present, reduction is best accomplished under general anesthesia by manual traction on the forearm in line with the deformity while an assistant gives counter-traction on the humerus While traction is continued one hand can be used



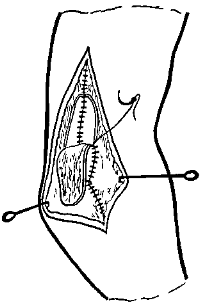


Fig 761. (*Left*) Lateral view showing extreme limits of mobilization occasionally necessary for reduction of these old unreduced elbow dislocations. (After Campbell.)

Fig. 762. (*Right*) Fibers of triceps muscle sutured following open reduction of an old unreduced elbow dislocation Aponeurosis of triceps is in process of being sutured. (After Campbell.)

to cause backward pressure on the upper ends of the radius and ulna in the region of the antecubital fossa When the dislocation is reduced, the elbow should be immobilized in acute flexion (approximately 40 to 50°) in a posterior molded splint for ten days.

Such a dislocation if associated with a fracture may require open reduction. Closed reduction should be attempted first and immobilization carried out as described above This not only often reduces the fracture as well as the dislocation, but the acute flexion

position for immobilization maintains both Another method of reduction is by skin traction on the forearm with the elbow in extension (Fig 763) However, if closed reduction or skin traction in extension are unsuccessful, or if the dislocation recurs, open reduction should be resorted to with fixation of the fracture fragments as described under the treatment of the specific fracture It is the fracture that so often causes recurrence of this dislocation In adults it may be advisable to treat the fracture and the dislocation by immediate open reduction, as earlier active motion can be instituted and functional return will be more nearly complete

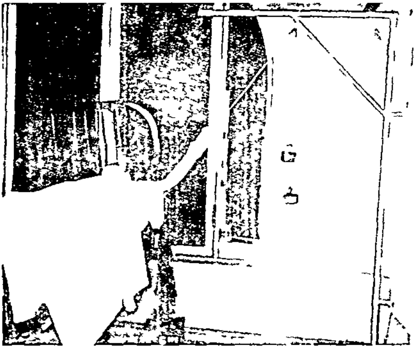


FIG 763 Dunlop s method of skin traction to forearm in reducing badly displaced supracondylar fractures Note posterior pull on shaft of humerus along with distal and anterior pull on lower fragment of humerus Bed should be tilted to opposite side to effect counter traction (Courtesy, Dunlop, J Jour Bone and Joint Surg, 21 69)

AFTER TREATMENT

In children the elbow should be kept in the splint for ten days if no fracture is present and for three to four weeks if there is a fracture Active exercises can be started as soon as the splint is removed and gradually increased A sling should be worn for from seven to ten days after removal of the splint In adults without an associated fracture the splint should be worn for ten days, but active exercises, thermolite or hot soaks, and massage should be started three or four days after the injury and increased gradually

In operated cases with firm internal fixation of the fracture no splint at all is necessary The elbow is immobilized in a sling only at about 70 to 80° Active motion is begun after three days and physiotherapy given as in the unoperated cases Extension actively beyond 120° should be guarded for the first three weeks to prevent redislocation of the radial head anteriorly After that time extension can be gradually and progressively increased

PROGNOSIS

This varies with the extent of the soft-part stripping of the anterior capsule and brachialis anticus muscle associated with the forward dislocation. Such stripping is apt to lead to thickening of the anterior capsule or to myositis ossificans, thereby causing limited flexion and extension It is rare that full elbow function is regained after such an injury. A very useful elbow, however, may be expected if the joint is not immobilized over a prolonged period and active exercises are begun early. In cases associated with fracture and also in those requiring open reduction the prognosis for function is never so good as in the simple dislocation, owing to the additional stripping of the soft parts at operation.

Divergent Dislocation of Radius and Ulna

This is also a very rare lesion, of which there are two types: the *anteroposterior,* where the ulna lies behind and the radius in front of the humerus; and the *transverse,* where the ulna lies to the medial and the radius to the lateral side of the humerus. In either type there is extensive damage to the ligaments and other surrounding soft parts.

TREATMENT

Reduction is affected by applying manual traction on the forearm with the elbow hyperextended and by manipulation, replacing first the ulna and then the radius by manual pressure If reduction of both of the bones is affected by this procedure, the elbow should be immobilized at approximately 70 to 80° of flexion in a posterior molded splint and sling. Should it be impossible to reduce either of the bones or hold both in reduction by this method, open reduction should be undertaken, because soft-part intervention is likely, especially a torn orbicular ligament that has folded on itself between the radial head and the lesser sigmoid fossa of the ulna. At open reduction the ligaments should be repaired *after* reduction is obtained and the elbow should be immobilized as in closed reductions.

AFTER-TREATMENT

Owing to the extensive ligamentous damage and to possible partial tear of the interosseous membrane, the elbow must be kept in the splint for approximately three weeks and at night for another two weeks Physiotherapy from the start in the form of baking (thermolite) and hot soaks, three to four times a day, massage once a day, and mild *active* exercises after the first week are important in reducing soft-part pathology and in regaining function. This routine should be carried out intensively for the first two to three weeks, following which the active exercises are stressed more than the heat and massage Passive motion or forced manipulations to increase elbow motion are inadvisable because of their tendency to add further soft-part damage and to cause pain and muscle spasm interfering with functional return

PROGNOSIS

Because of the severe trauma involved in this type of dislocation, producing extensive soft-part damage, the prognosis must be guarded. There is by virtue of this damage a marked tendency toward redislocation, especially of the radius. There is also a tendency toward the formation of myositis ossificans in the brachialis anticus muscle and to calcification in the healed capsule, either of which may cause some limitation of flexion and extension at the elbow joint. Not only is function more often impaired, but also the disability time is prolonged (three to four months).

Anterior Dislocation of Radial Head

Anterior dislocation of the head of the radius is most commonly associated with fracture of the middle or upper third of the shaft of the ulna, the apex of the angulation directed toward the volar surface of the

forearm This combination of fracture and dislocation is often spoken of as Monteggia's fracture It occurs far more frequently in children than in adults If the apex of the ulnar angulation points toward the dorsal surface a fracture of the radial head rather than a dislocation is the usual sequence occasionally the radial head dislocates laterally or posteriorly but never anteriorly

The radial head may dislocate by tearing through the orbicular (annular) ligament or this ligament may remain intact and the radial head may pull out from beneath it—i e through the distal margin of this ligament In either case the articular surface of the radius no longer articulates with the capitellum The orbicular ligament whether torn or untorn may lie behind the dislocated head of the radius Because of this the reduction may be very difficult by closed manipulation or difficult to maintain by any position of flexion after manipulation It will be impossible to reduce it at all in those cases where the head has pulled out from beneath the orbicular ligament Some authors say that it can always be reduced by closed methods but cases have been seen where even at open reduction the orbicular ligament had to be divided before actual reduction of the radial head could be accomplished

In the position of anterior dislocation the radial head mav cause enough pressure on the radial nerve to bring about a paralysis of the wrist and finger extensors (posterior interosseous nerve)

The importance of the diagnosis lies in the recognition of the dislocation This is not always as easy as it may seem particularly when there is an obvious deformity of the midshaft or upper shaft of the ulna Here the x rays taken may not include the radiohumeral articulation in good lateral projection and one s attention becomes centered all too readily on the obvious fracture of the ulna It should be *axiomatic* that once a fracture of the upper ulna is seen with angulation and no fracture is seen in the radial shaft either a dislocation or fracture of the radial head must be considered to be present until otherwise disproved by adequate lateral x ray films of the elbow joint

The best way to make this diagnosis or to rule it out is to have x ray films taken of both elbows in the lateral position The axis of the shaft of the radius when projected upward normally passes through the center of the capitellum regardless of the amount of flexion or extension at the elbow

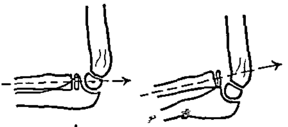


FIG 764 Illustrating normal axis of shaft and head of radius (A) passing through center of capitellum in lateral view and anterior dislocation (B) of head of radius associated with fracture of upper shaft of ulna with anterior angulation of latter (This combination is commonly known as a Monteggia fracture)

If this is not the case a diagnosis of radial head dislocation is obvious (Fig 764) This applies to children as well as to adult elbows

TREATMENT

Closed Reduction This is often possible The angulation of the ulna fracture should be corrected before reduction of the radial head is attempted The radial head is then manipulated into position with thumb pressure over its anterior aspect while manual traction and adduction on the forearm is carried out Maintenance of this reduction is then held by immobilizing the supinated forearm in a posterior molded splint with the elbow in about 70° of

flexion. It is important, however, to be sure that angulation of the ulna fracture does not recur. If it does, one may expect to see the radial head redislocate Post-reduction x-rays should be repeated in one week and again at two weeks to make sure redislocation has not occurred

Time of Immobilization. This should be in the neighborhood of from three to five weeks, or, in other words, until the healing of the ulna fracture is sufficiently strong to preclude further angulation of this bone. Following the removal of the plaster splint, the elbow should be carried in a sling for another ten days to two weeks, during which time active motion (flexion and extension) must be practiced and encouraged every one or two hours.

Open Reduction. This may be resorted to immediately as the best form of treatment if proper facilities and technic are available. It will be obligatory when it is impossible to reduce or hold reduced the head of the radius by closed methods, or where some time afterward (one to two weeks) the head again redislocates Where any nerve involvement is present, open reduction is the safest and surest method for treating both conditions

The approach for open reduction is through an anterior Z-shaped incision over the anterolateral aspect of the elbow joint (Fig. 757). This allows a relatively bloodless exposure of the lateral side of the elbow joint and the radial head via an intermuscular approach. The radial nerve and all its muscular branches can be retracted laterally and thereby kept from danger of injury. The recurrent branches of the radial artery and vein must be divided, but otherwise the approach to the joint is free of vessels The radial head and neck should be lifted forward and the torn orbicular ligament retracted, or, if untorn, it should be divided and retracted to allow reposition of the radial head in the lesser sigmoid fossa of the ulna. The torn ends of the orbicular ligament are then approximated in front of the head and sutured with mattress sutures of silk The remaining capsule is closed where necessary with interrupted fine silk sutures. The wound should be closed in layers as usual.

The angulated ulna fracture may be reduced closed or by open reduction at the same time, depending upon the circumstances of ease of reduction and of maintenance of reduction. It is frequently wise to apply internal fixation by metal plate and screws to the ulna in order to insure that the good job of open reduction on the radial head may not be spoiled by subsequent angulation of the ulna.

In order to avoid the necessity of making a second incision for open reduction on the ulna fracture, the approach recently described by Speed and Boyd is an excellent one. It exposes the fracture site in the ulna and the dislocated radial head adequately through a single incision and also gives ample protection to the deep branch of the radial nerve. The incision is started one inch above the tip of the olecranon on the lateral margin of the triceps tendon. It then follows this tendon distally to its insertion, thence along the subcutaneous dorsal margin of the ulnar shaft as far as necessary. The periosteum of the ulna is split and this, along with the anconeus and supinator muscles, is elevated subperiosteally from the dorsolateral surface of the ulna. The deep fibers of the supinator muscle are divided close to the ulna. By doing so, the deep branch of the radial nerve (which lies between the superficial and deep layers of this muscle) is reflected along with the muscle and retracted out of danger. The ulna fracture is then reduced, and, if necessary, fixed with a plate and screws. The radial-head dislocation is likewise reduced and the orbicular ligament repaired with silk sutures. If this ligament is too torn to repair, a strip of deep fascia one-half inch wide by four inches long attached at its upper end to the ulna may be passed around the neck of the radius and sutured to itself to form a

new orbicular ligament (Figs 765, 766 767) [For the reconstructive repair of late cases this is an excellent approach For early cases many men prefer the dual approach —Ed]

Following open reduction the treatment is the same as for the closed method except for the fact that active exercises and use are started at the end of three weeks if internal fixation has been employed but at five to six weeks if closed methods have been employed

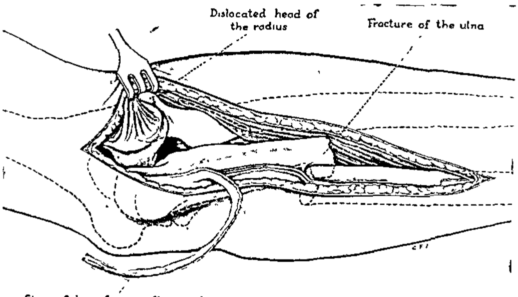
Late Cases (Old Unreduced Dislocations of Radial Head)

In late unrecognized cases of anterior dislocation of the radial head there may be no symptoms or complications Follow up examination and x ray films show an enlarged mushroom shaped radial head This may impinge on the humerus in acute flexion giving limited motion and pain or it may slide outward past the lateral humeral condyle on flexion and cause no

Fig 765 Lateral view of acute fracture of ulna with dislocation of head of radius in patient aged 20 years (Courtesy Speed J S and H B Boyd Jour Amer Med Asso 115 1699)

If a radial nerve palsy is present the hand and fingers should be cocked up in an extension splint to aid recovery The cock up splint may be made of molded plaster-of paris bandage and should be adequate to prevent flexion of the wrist and fingers It should extend from the upper forearm to beyond the fingertips should hold the wrist in approximately 45° of extension and should keep the fingers and thumb fully extended Posterior interosseous nerve palsy or paralysis will usually recover in from four to eight weeks if thus treated When active finger and wrist extension are recovered the splint may be discarded but not before

symptoms If it causes symptoms or disability it should be removed Another complication due to unreduced anterior radial head dislocation is a late ulnar nerve palsy manifested by hypesthesia along its terminal sensory distribution or interosseous muscle weakness in the hand or both The mechanism of this late ulnar nerve disturbance (and it has been observed as late as nine years after injury) is due to the increased carrying angle of the forearm in the absence of the normal stabilizing influence of the lateral side of the joint This increased carrying angle when the elbow is fully extended causes the olecranon to impinge medially upon the ulnar nerve eventually



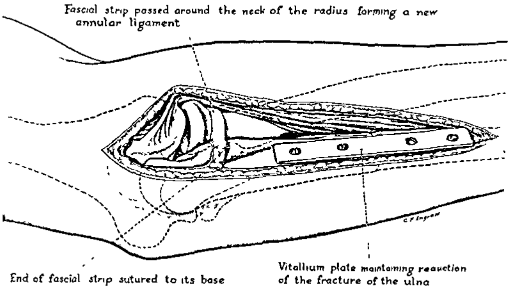


FIG 766 (*Top*) Drawing of incision described in the text Anconeus and supinator muscles have been reflected from ulna, revealing head and neck of radius A strip of deep fascia has been elevated from forearm and left attached proximally (Courtesy, Speed, J S, and H B Boyd Jour Amer. Med Asso, 115 1699)

FIG 767 (*Bottom*) Operation completed Fracture of ulna has been reduced and a vitallium plate applied for fixation. The strip of fascia has been passed around neck of radius and sutured to itself, forming a sling for maintaining reduction of head of radius (Courtesy, Speed, J S., and H. B. Boyd. Jour Amer Med Asso, 115 1699)

contusing it or causing inflammatory thickening of the fibrous sheath over it due to repeated trauma The increased carrying angle may also cause stretching of the ulnar nerve If the condition is progressive (and it should be watched very carefully) it may be relieved by operative transplantation of the ulnar nerve anterior to the medial condyle of the humerus

Subluxation of Radial Head

This condition, often called a "pulled elbow, occurs almost entirely in children under the age of six years It is caused by sudden lifting pulling, or jerking on the child s arm Pain and refusal to use the arm are characteristic symptoms There is no deformity and no localized tenderness The x ray picture discloses no bone or joint pathology The actual lesion probably consists of a partial subluxation of the radial head with possibly a pinching of a synovial fold

TREATMENT

The treatment consists of reduction by steady, slow, complete supination of the forearm with gentle outward pressure on the radial head Immobilization in a sling for one or two days after reduction is sufficient

PROGNOSIS

The prognosis is excellent for full function and use

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32

Treatment of Fractures of Bones of Forearm

PAUL B MAGNUSON, M D.

ANATOMY AND PHYSIOLOGY*

In the approach to treatment of fractures of the bones of the forearm, just as in fractures elsewhere in the body, there are certain fundamental factors to be considered, namely, the relation of the fractured bones to the adjacent structures and the potential influence of surrounding tissues upon the reduction and maintenance in position of the bones themselves The ulna must be considered an extension of the arm downward to the wrist, concerned in motions of strength at the elbow The radius must be considered an extension of the hand upward, concerned in motions of dexterity of the hand Despite the fact that the radius has attached to its upper end a strong flexor of the elbow (the biceps), the ulna receives and transmits motions of force over a broad surface to the lower end of the humerus The radius rotates around the ulna, there being a joint between the two bones at the end of each To avoid (1) angulation between the fragments, (2) difference in rotation between the fragments, (3) shortening of either bone without commensurate shortening of the other bone, and (4) to preserve the normal arc of rotation of the radius around the ulna, fractures of these bones must be accurately reduced

The angular pull of certain muscles—namely, the pronator quadratus, pronator teres, supinator brevis, and biceps—has a tendency to displace the bones laterally toward each other, to flex one fragment without flexing the other, and to rotate one fragment without rotating the other, depending on the location of the fracture Further, the strong fibrous membrane descending obliquely downward and inward from the interosseous ridge of the radius to that of the ulna starts about one inch below the tubercle of the radius and extends to the wrist It serves to connect the bones and to increase the extent of the attachment of the deep muscles In some cases there is an extra layer in the middle of the forearm which descends from the ulna to the radius toward the wrist, in a direction contrary to that of the other fibers (Fig 768)

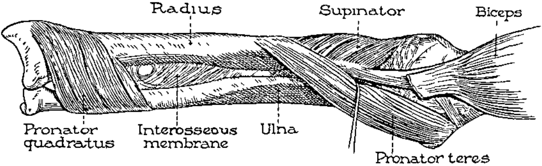
It will be seen, therefore, that there is a complicated muscle attachment, with cross pull as well as longitudinal pull of the flexors and extensors of the wrist and fingers Also, the interosseous membranes complicate matters if the fragments are badly displaced, because there is no method with which the author is familiar (except open reduction) which will replace the ends of the fragments if any of them are entangled in this membrane

In addition to these factors there is a strong fascia completely surrounding the forearm, extending from the elbow to the wrist A complete fracture of the bones of

* The material under the heading Anatomy and Physiology should be read in connection with each fracture described in order to have in mind the principles on which this injury is to be treated.

the forearm always causes severe hemorrhage around the ends of the fragments, which results in immediate and rapid swelling and bulging of this surrounding fascia and the muscles beneath it. This in itself shortens the distance between the elbow and the wrist by causing the fascia to bulge out essentially in the form of a triangle.

When all these factors are taken into consideration it will be seen that there may be lateral displacing effect by muscle pull (pronators and supinators), longitudinal displacing effect (flexors and extensors), rotating effect (pronators and supinators); obstruction to replacement by entanglement of fragments in the interosseous membrane, and obstruction to longitudinal replacement by distension and consequent shortening of



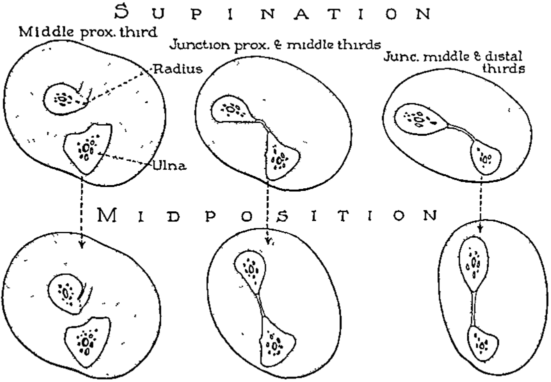


FIG. 768. (*Top*) Muscles of forearm exerting significant influence, and interosseous membrane. Note direction of fibers in interosseous membrane.

FIG. 769. (*Bottom*) Relations of forearm bones to one another at various levels in supination and in midrotation This is a guide to the position of immobilization at these levels.

the fascia surrounding the forearm In order to obtain a satisfactory result these circumstances must be overcome if they exist Thorough understanding of the anatomy mechanics, and physiology of the forearm is essential to an analysis of any fracture or combination of fractures or displacement This is necessary before reduction is attempted or any decision is made as to the best method of treating the fracture at hand (Fig 769)

General Considerations

Fractures of the forearm should be considered emergency cases They should be reduced promptly and properly as soon as the patient can be brought to a place where he can be anesthetized or local anesthesia can be used between the fragments under proper surgical technic If it is impossible to bring about proper reduction by any closed method, operation should be performed as soon as the patient can be placed in proper surgical surroundings and surgical hands The bones of the forearm are small in diameter, intricate in mechanism, and more or less fragile They will not stand too much manhandling Therefore, the earlier the operation is performed the less contracture of muscles and the greater ease of reduction

A separate incision should be made for each bone and the approach should be where the bone lies closest under the skin, with the incision slightly displaced so that the skin will not become adherent immediately over the bone The muscles should be separated and not lacerated in the dissection The ends of the fragments should be brought together accurately and fixed in such a way that muscle pull will not again displace them This may sound simple, but not infrequently it is a matter of considerable technical skill and judgment because of the size of the bones and the difficulty of fitting mechanical apparatus to the acute curve of the circumference The average bone instruments are much too large for the radius and ulna and, if an instrument does not fit it is easy to displace one group of fragments while adjusting those of the other bone

If the fracture has remained unreduced for some time while skin abrasions are healing there may be difficulty in bringing the fragments end to end because of the contracture of the controlling muscles Inasmuch as it is necessary to provide fixation that will resist angulation as well as rotation, the splinting apparatus, whatever may be chosen, must be firm and remain firm in its hold on the bone until sufficient callus has formed at the fracture site to immobilize it permanently

Choice of Material for Fixation

For an oblique fracture probably the simplest method of fixation is by one or more screws of metal ivory, or bone, the screws being put through at various angles so as not to permit pivoting or rotation In other words they should not be placed parallel to each other or in a direct line with each other if it is possible to avoid this Transverse or slightly comminuted fractures, I believe, are best treated by a plate with not less than four and preferably six, holes

The choice of plate is important Non electrolytic material such as vitallium is certainly preferable Vitallium however, is a cast metal and will not permit of bending or twisting and is sometimes very difficult to fit to the small circumference of either the radius or the ulna Further, with the vitallium plate it may be necessary to cut a bed in order to make the plate fit accurately

Dr William Darrach and Dr Clay Ray Murray have introduced a steel of high nickel, low-chrome content which is very thin for its strength and sufficiently pliable to be bent, with rather heavy instruments to allow more or less molding This is the most satisfactory internal fixation apparatus of its kind that the author has found

The average Sherman plate as made by many instrument makers is unreliable in composition, and the author has seen too many either break or bend, depending on the temper of the metal, to trust anything but a highly specialized metal plate to apply on bone. [This was true to some extent of the Sherman plate when made of vanadium steel. They are now made of a chrome-nickel stainless steel plus a small percentage of molybdenum which renders them tough, malleable, and nonirritating in the tissues. They are now very satisfactory See Chapter 22.—Ed.] The screws used in any out through the opposite side of the other fragment in a plane at right angles to that of the screws which fasten the plate. [This is the method which was introduced as a routine procedure some years ago on the Fracture Service of the Presbyterian Hospital in New York City.—Ed]

Insertion of the screws at various angles, obliquely, as described above, risks stripping of the thread against the edge of the screw hole in the plate during the insertion By one means or another, however, the torsional strain must be met to secure adequate fixation and to minimize the risk of

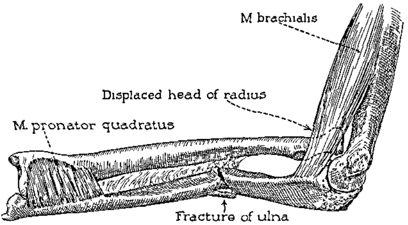


FIG. 770 Monteggia fracture with characteristic displacements.

of these plates should be of the machine-screw type with a tap end, and should be long enough to reach from the surface of the plate through the opposite cortex. If these screws can be put in at a slight angle it will take up the torque, relieve the threads of strain by opposing the angle of the screws, and prevent loosening of the screws, as sometimes occurs when they are put in in the same line and are parallel to each other without provision against torsional strain.

Instead of inserting the screws at various angles, one can insert them all at right angles to the surface of the plate, but provide against torsional strain by a cross-fixation screw running from one side of one fragment across the fracture line and absorption about the screws. The long narrow plate with six-screw fixation and screw cross-fixation is possible through the use of screws of smaller caliber than the screws used in larger bones, and which cut an accurate thread in a drill hole made by a standard No. 41 drill instead of the No. 32 or 33 drill used for the ordinary screw. [See Operative Reduction and Fixation, Chapter 22.—Ed.]

A plate should never be put on the bone immediately under the skin. It should be covered by muscles so that the ultimate scar in the skin will lie to one side or the other of the bone This prevents irritation and adhesion of the skin to the immediately underlying bone, which is always uncomfortable and certainly does not favor

prompt and nonirritated healing [See Operative Reduction Chapter 22 —Ed]

In the discussion of treatment of the various fractures of the bones of the fore arm the basic principles set forth in this introduction must be considered in their application to the individual fracture

FRACTURE OF UPPER THIRD OF ULNA AND FORWARD DISLOCATION OF HEAD OF RADIUS

In this complication of displacement (see also Chapter 31) the orbicular ligament around the head of the radius is torn and the radial head is displaced forward and impinges on the anterior surface of the lateral condyle of the humerus The distal fragment of the ulna is also carried forward at the time of injury and the distal end of the upper fragment forms with it an angle pointing volarly and open dorsally (Fig 770)

Reduction

With the elbow flexed and with counter traction applied to the front of the humerus at its lower end traction should be made on the forearm It is usually easiest to apply this at the wrist joint The radius is pulled downward and at the same time the head of the radius is pressed backward by the thumbs of the operator It is usually not difficult to press the head of the radius *down into what seems to be its normal* position In order to hold it in this position the elbow must be brought into extreme flexion otherwise the biceps pulls the head forward again almost immediately

Sometimes the orbicular ligament folds in under the head of the radius and prevents its replacement In such a case it is necessary to open the radio ulnar joint and then reduce the head and suture the ligament—or at least hold the arm in acute flexion to prevent redislocation of the head of the radius after the orbicular ligament has been replaced in proper position

The ulna may remain displaced after reduction of the head of the radius The triceps is attached to the upper fragment posteriorly at the upper end The brachialis anticus pronator teres and supinator brevis are attached lower down anteriorly, and the interosseous membrane between the ulna and radius complicates the handling of the upper fragment to the extent that it is necessary in the majority of cases to do an open reduction and operative fixation The fractures are usually transverse or short oblique and are not easily fixed by a single screw Therefore a plate applied in accordance with the principles described above on the flat side of the bone (which is the medial side) will often best solve the problem

If the position of the ulna can be maintained with the elbow in sufficient flexion to keep the radial head reduced the arm is immobilized in that position Immobilization can best be accomplished by plaster extending along the dorsum from the level of the axilla down to and including the wrist and the base of the hand with the forearm in full supination This posterior plaster splint will sufice and will fit better than the usual commercial splint Care should be taken not to cause pressure over the olecranon or the bony points of the condyles The plaster should be supported by a second strip of plaster or adhesive extending from the wrist to the upper end at the level of the axilla to overcome the tendency of the elbow to come into extension This position can be attained or held only if the radius is completely reduced

No force should be applied in putting the arm in full flexion if the head of the radius is properly reduced no force will be necessary The skin fold on the flexor surface of the elbow should be protected with a very light pad and it is advisable to leave the fold of the elbow exposed so that skin maceration may be prevented If a posterior splint and a strip of supporting material between the wrist and the upper end of the splint on the upper arm as described

above is used, it will leave an open triangle through which this can be done.

Immobilization in this position should be continued for from three to five weeks to allow healing of the ligaments supporting the head of the radius. After this time relaxation of acute flexion may be attempted very gradually and without force, by simply straightening the splint and allowing the patient to carry the arm in a sling, still maintaining support over the full length of the ulna. If the dislocation has been operatively reduced, the orbicular ligament sutured, and the ulna fixed with a plate firmly, then relaxation of the acutely flexed position may be started in from ten days to two weeks.

Some men advise that the ulna first be fixed by operation as described, and that the radial head then be exposed and the orbicular ligament repaired through an anterior incision. This advice is based on finding in a respectable proportion of the cases operated upon that the torn orbicular ligament lies in a folded mass completely behind the radial head when the latter is replaced, or that the radial head has buttonholed the capsule anteriorly without rupture of the orbicular ligament, and lies with intact capsule between it and its normal position.

In the former instance the threat of chronic dislocation or subluxation when the elbow is extended is eliminated by fishing the torn ends of the orbicular ligament from behind the radial head with a small sharp hook, and suturing them together in front of the radius with fine silk sutures. In the latter instance, the intact capsule, which prevents replacement of the head, can be longitudinally incised, the head replaced, and the capsular rent repaired. [The anterior approach used is described and illustrated under Fractures Involving the Elbow Joint, Chapter 31.—Ed.]

If it is necessary to resect the head of the radius after the ulna has united, it can be done through a short radio-ulnar longitudinal incision and division transversely of the radio-ulnar ligament. With a thin sharp chisel the radius is cut at its narrowest portion, just below its contact with the ulna at the upper end The radial nerve lies anterior to and toward the ulna from the radius at this point, and the chisel must stop before it is driven beyond the proximal cortex By rotating the radius, the successive chisel cuts will section the whole cortex without danger to the nerve.

It is the author's opinion that operative fixation of the ulna is the procedure of choice in these injuries provided the head of the radius can be reduced completely. If this cannot be accomplished, the joint should be opened and the orbicular ligament sutured before the ulna is operatively fixed. Otherwise it is very difficult to reduce the ulna and hold it in reduction. Reduction of the head of the radius, therefore, should be complete, and it should be firmly held as the ulna is fixed.

It may be that, although the ulnar fracture so fixed heals in perfect position, when the elbow is removed from fixation apparatus it will be found that the head of the radius is ankylosed, or that it redislocates on extension of the elbow. Removal of the head is indicated if ankylosis has occurred. This should not be done, however, until the ulnar fracture has firmly united If it is removed prior to union, the author knows of no way to hold the ulnar fragments in alignment They will angulate in spite of almost any external fixation Even if the head of the radius is damaged at the time of the original injury and its ultimate removal seems inevitable, it should be left in place in order to buttress the ulna while it is healing. [The procedure for removal is described under Fracture of the Head of the Radius, Chapter 31.—Ed.]

If, upon releasing the arm from fixation in flexion, the head of the radius redislocates when the elbow is extended, it may be replaced or resected subject to the provisions of the previous paragraph. If any

angulation or shortening of the ulna has occurred during the period of fixation, however, operative replacement of the radial head cannot be done unless the ulnar deformity is corrected operatively at the same time, as described above

FRACTURE OF SHAFT OF ULNA WITHOUT FRACTURE OF RADIUS

Above Insertion of Pronator Teres

If the fracture is transverse or nearly transverse so that there is good abutment at the ends of the fragments it may be reduced by straight traction and counter traction It is advantageous to apply counter traction by placing a strong muslin bandage or sheet around the patient s body at the level of the axilla and tying him to the table on the side opposite the fracture A bandage loop may be thrown around the patient s wrist and over the shoulder of the operator This leaves both hands free for manipulation and steady strong smooth traction may be applied with both hands free to jockey the fragments into position As previously stated the pronators and supinators have a minor effect on fractures of the ulna above the pronator teres and once this simple fracture is in alignment fixation with a circular plaster or padded molded splint in the position of right angled flexion and midpronation will usually suffice to retain the fragments The immobilization should extend from the metacarpophalangeal junction to the axilla If the arm is held in too much flexion the triceps may tend to angulate the fragments posteriorly This can be overcome by further extension of the arm

The immobilization is required for from six to eight weeks during which time active use of the hand and fingers and of the shoulder should be enforced The shoulder stiffness which often results in adults from the constant wearing of a sling is thereby avoided Following removal of the plaster active exercise aided by the usual physical therapy measures is used and the expected period of disability is from six to ten weeks to give the soft tissues a chance to become flexible and regain their strength

Below Insertion of Pronator Teres

Fracture of the shaft of the ulna below the pronator teres is somewhat more difficult to hold in position because of the strong pull of the pronator quadratus (Fig 768) which has a definite tendency to bring the radius and ulna into approximation In this location the triceps has less effect

Reduction is made in the manner above described but *it is more difficult to hold* After reduction by traction and counter traction a double board splint with firm padding which presses between the radius and ulna is the most satisfactory method of treatment The splints must be kept firm by bandages and must not press on the radius or ulna laterally but rather have a tendency to force the muscles of the fore arm between the radius and ulna by the pressure of the central padding with the arm between midrotation and full pronation (Fig 771)

It is best to include the elbow in the *splinting to prevent too free use of the fore* arm It may be found that the position of full pronation will be necessary to prevent the pronator teres from displacing the ulnar fragment toward the radius (Fig 768) The external immobilization will be extended just slightly above the elbow and need not run as high as in fractures of both bones of the forearm The use of circular plaster is not advised because of its tendency to press the radius and ulna together thereby aggravating the tendency of the ulnar fragments to move toward the radius

After the fragments have become partially united the elbow may be removed from the splint and exercised at frequent intervals but the hand should be held in pronation until all chance of angulation toward

the radius has been eliminated by solid bony union. It has been the author's experience that these fractures heal rather slowly. Prognosis should be guarded, and immobilization should be continued until there is sufficient callus to hold the fragments in position. This will be not less than eight weeks in most cases, and in some cases will be three to four months.

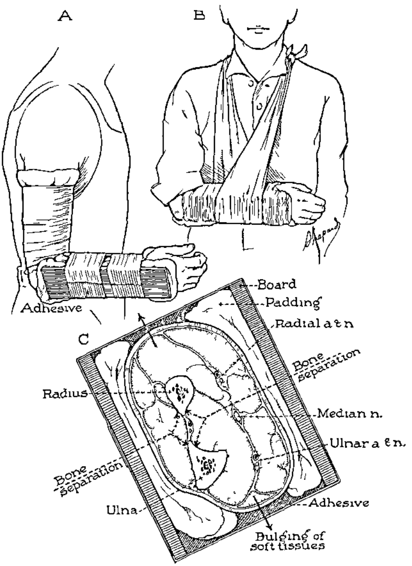


Fig. 771. Forearm splinting to insure maximum separation of individual bones Note absence of any force tending to compress bones laterally in (C). In (A) an inside L-splint is used to immobilize elbow. (B) depicts method of sling suspension.

In either of these fractures, if it is impossible to reduce the fragments and hold them in reduction by closed methods, open operation should be performed within the first ten days after injury. The operative approach to fracture of the ulna is simple because the ulna lies immediately under the skin in its full length. Incision is made on the extensor surface immediately over

the extensor carpi ulnaris, which lies more dorsal from the ulna than ventral The dorsal surface of the bone will be found more nearly flat than the ventral The flexor profundus digitorum extends around anteriorly and both these muscles may be retracted subperiosteally to expose the ends of the fragments as much as necessary to bring them into proper alignment and rotation The plate should be fixed beneath the muscles not under the skin and the incision should be made preferably to one side so that it will not run immediately over the bone where it lies just under the fascia In the lower part of the forearm the incision is made lateral and a little anterior to the ulna with the arm in pronation, because in this location the anterior surface of the ulna is more nearly flat than the posterior surface and the plate may be applied more easily

There should be no occasion to approach the ulnar nerve if the muscles are separated subperiosteally from the bone since the nerve lies anteriorly just under the flexor carpi ulnaris

Fixation and treatment is the same following operation as is that described in the closed method

The ulna is small in diameter and somewhat irregular, but usually a narrow plate with not less than four screws can be applied firmly to the side of the bone, and this is the fixation method advised The plate should never lie immediately under the skin it should be buried beneath the muscles [See Operative Reduction Chapter 22 —Ed]

FRACTURE OF SHAFT OF RADIUS

Above Insertion of Pronator Teres

Fracture of the radius in this location should be reduced as is fracture of the ulna, except that it should be immobilized in complete supination with the elbow at a right angle to relax the pull of the biceps and the supinator teres, which are both attached to the upper fragment In other words, the upper fragment is entirely under the control of its muscle attachments, and the lower fragment must be brought into alignment and rotation with the upper fragment

Transverse fractures may be treated by immobilization in the type of splinting referred to above under fracture of the upper ulna, and the after care is the same as for those cases Oblique fractures, however, will need more careful supervision, because if the radius is even moderately shortened with the ulna intact, the radio ulnar joint at the lower end of the two bones will be distorted, with the threat of subsequent pain on forced rotations Correction of a rotation deformity also must be perfect, or the dexterity of the hand will be affected by the loss of either pronation or supination depending on the degree of discrepancy in the rotation relationship of the fragments

If shortening of the radius and rotation deformity cannot be accurately controlled by any closed method, open reduction should be resorted to, and this should not be delayed beyond the first week It is extremely important to the dexterity of the hand to have complete and normal function in the radius Therefore no halfway measures should satisfy the surgeon since they will not satisfy the patient if the arm is disabled

Pin in plaster methods (that is with one or more pins inserted in each of the fragments to control rotation of the radius) may be useful in a very limited number of cases The author feels that there is no more risk in opening a fracture and fixing it with a plate than there is in drilling two to four holes through the soft tissues and bone, and allowing pins fixed in plaster to remain in position for weeks Further, these bones are sometimes fragile and the fragments can be disrupted by twisting and prying in an effort to get them back into position Where there is rotation and over

lapping and angulation to overcome, the pins are not satisfactory.

Below Insertion of Pronator Teres

After reduction by traction and countertraction, as described for the ulna, the arm should be held in right-angle flexion at the elbow, with the hand halfway between pronation and supination Fixation should be made either with anterior and posterior molded splint from the axilla to the hand, or with circular plaster over the same area. In all fractures of the forearm the author prefers pressure exerted between the bones with avoidance of all pressure on either side and, if circular plaster is used, he frequently puts on an anteroposterior padded board splint to maintain the anteroposterior pressure and relax lateral pressure. It makes a clumsy dressing so far as the sleeve of a garment is concerned, but it holds the muscles firmly between the radius and ulna and has a tendency to prevent synostosis (Fig. 771).

Immobilization should be for not less than eight weeks. Frequently these fractures take much longer to establish union. Fingers and thumb should always be open and should be kept moving in flexion and extension, which promotes the circulation and inhibits the formation of adhesions around the delicate tendons and sheaths controlling the fingers

Frequent checking with x-rays is necessary to assure that the lower fragment of the radius is not pulled out of position by the action of the pronator quadratus. If this becomes evident, and it is impossible to overcome it by traction and countertraction, open operation should be performed

There are undoubtedly some cases in which the pin-in-plaster method, heretofore referred to, is applicable. In a compound or badly comminuted fracture, pins inserted into the main upper and lower fragments can be used to reduce and adjust the fragments, after which the pins can be incorporated in the fixation cast. In the hands of those who are skillful mechanically the method might be preferable to any other. It is difficult to lay down rules for any fracture or group of fractures, but the pin-in-plaster method should be kept in mind as a possible solution of a bad situation.

The plate method, however, is usually most satisfactory, and, as said before, the plate should have not less than four screws inserted, two above and two below the fracture. If the fragments can be firmly locked together, sometimes it is unnecessary to place any retention within or on the bone. It depends entirely on the serration at the ends of the fragments and how well they can be fitted one into the other. *Caution:* This is not true, however, in most fractures of both bones of the forearm, because if the support of the opposite bone is lost, rotation and angulation may take place and the muscle pull will distort the fragments even when they have been well apposed.

FRACTURE OF BOTH BONES OF FOREARM

If open reduction is decided upon, the approach to the radius is more complicated than the approach to the ulna (Fig 772). In its upper half, the radial nerve lies anterior to and toward the ulna from the radius and, especially in the upper third, can be injured by instrumentation. It supplies the brachioradialis and the extensors of the wrist, which lie anterolateral and anterior with the hand in supination Looking at it from above, with the hand pronated it throws the radius almost under these muscles, so that the approach can best be made posterior and a little lateral, between the common extensors of the fingers and the extensor carpi radialis. The former is then retracted toward the ulna and the latter is retracted in the opposite direction. Since this dissection is carried out in the extensor compartment no vessels or nerves will be encountered except the superficial branch of the radial. Injury to this nerve

will result in impairment of sensation but no loss of motor function Below the upper third there is little or no danger of injuring any part of the radial nerve because below this point it is practically nothing but a few sensory fibers

sheaths should be retracted The tendon sheaths should not be opened unless they have been injured at the time of fracture There should be gentle retraction with smooth retractors and the plate should be placed on the flexor surface Attention is

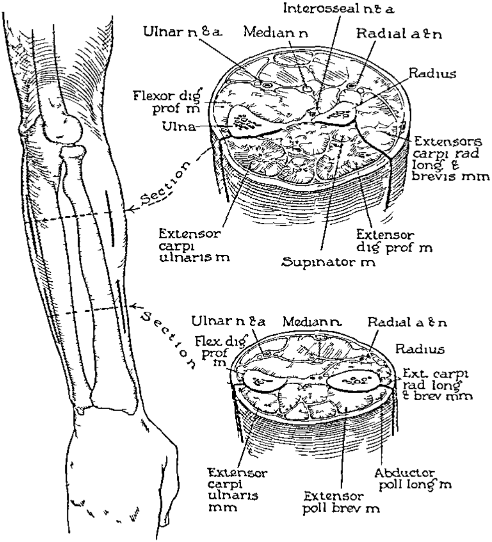


FIG 772 Operative routes for forearm bones at upper and lower levels These routes insure minimum laceration to tissues and maximum avoidance of important vascular and nerve structures

If a plate is applied after open reduction it should be placed on the dorsal surface considering the hand in supination In fracture below the middle, the approach may be in line with the thumb on one or the other side of the radius, but not immediately over the bone The tendons with their called to the fact that below the middle this bone is quite flat on the posterior surface and in this location the plate can be buried in deeper position and more easily fastened

The length of time for immobilization is the same in both upper and lower fractures Although the upper one usually heals in

less time than the lower, there is no fixed rule, and the cross pull of the pronators and supinators is always to be reckoned with.

Immobilization apparatus should always extend above the elbow, with an angle at the elbow to prevent pronation and supination. In the upper fracture midposition is best. In fracture around the middle, full pronation is sometimes advisable. This must be selected for the individual case. It is advantageous here also to use two well-padded rather stiff board splints (one anterior, the other posterior) supported by plaster which extends above the elbow, because compression of the radius and ulna toward each other is to be exerted to force the muscles of the forearm between the bones, thereby in some measure controlling the constant tendency of the pronator quadratus to bring them together (Fig. 771). [See Fracture Reduction in Chap. 22.—Ed.]

Prognosis in fracture of the radius should be guarded as to the length of time before union.

Without Displacement

Fracture of both bones of the forearm without displacement, or with very slight displacement, may be treated by circular plaster, with the forearm preferably at a right angle with the upper arm midway between pronation and supination, or by a combination of splint and cast—that is, anterior and posterior board splint surrounded by plaster. As in all fractures involving the forearm, the plaster or other immobilizing apparatus must extend above the elbow, preferably to the axilla. Only in this way can rotation of the radius be prevented and normal relationship maintained, so far as rotation is concerned, between the fragments.

With Displacement

It is not always possible to reduce a fracture of both bones of the forearm by direct traction or by manual manipulation. The method of employing traction and manipulation is that described above for fracture of a single bone

Traction may be extended over a longer period with the patient in bed or on a table, by the use of weights if manual efforts fail (Fig. 773). A snug felt cuff is placed around the wrist, with canvas or adhesive plaster applied over it, and the forearm is suspended perpendicularly at a right angle to the upper arm, which is in abduction Counter-traction may be applied to the lower end of the humerus by weights hung over the upper arm with the elbow extending beyond the side of the bed or table, or by a sandbag of considerable weight laid across the flexor surface of the upper arm as close to the elbow as possible. Continuous traction may thus be made over a period of hours or days—preferably hours—until the muscles are sufficiently stretched to allow the fragments to be brought end-to-end.

While this heavy traction is being applied, the patient should receive an opiate or anesthetic, which will facilitate the relaxation of the muscles. It may be advantageous to use 20 to 30 pounds of traction for 24 hours rather than less weight for a longer period. Any excess weight is removed when reduction has been attained A circular plaster is applied from the axilla to the metacarpophalangeal joints as the arm is suspended in traction with the elbow at a right angle and the forearm in the degree of rotation which seems best for maintenance of that particular fracture. In the upper third it will be supination; in the middle third, midway between pronation and supination; and in the lower third, from midway between pronation and supination to complete pronation. Attention is again called to the fact that immobilization apparatus should not come below the metacarpophalangeal joints.

Here again, before traction is removed it will be found of advantage to put on a double board splint while the arm is still in suspension, and then incorporate the

whole in a plaster casing Once reduced, the fracture should not be tampered with If a good strong bony union occurs in two months the result may be considered happy if it takes longer it is not unexpected

Fluoroscopic visualization in reduction when the muscles have been stretched, is an advantage when it can be used The fixed traction has the advantage of allowing the application of circular plaster under anesthesia when the fragments are reduced without changing the position, as plaster may be applied over the forearm and upper arm without disturbing the suspension or traction It will be found that a circular plaster which is not wrapped too tightly, but which is molded to be more or less flat from front to back and presses on the flexor and extensor surfaces, will hold the position better than one wrapped snugly at the sides The latter has a tendency to press the bones toward each other

If the surgeon is a good engineer, thoroughly versed in geometry and trigonometry, he may use the pin in plaster method with some success in fracture of both bones of the forearm The author s experience, however, has been that while one fragment is being manipulated in the other slips out, and he prefers to fasten each bone and be sure it will stay where it has been placed [See Chapter 22 for placement and method of use in pin and plaster —Ed]

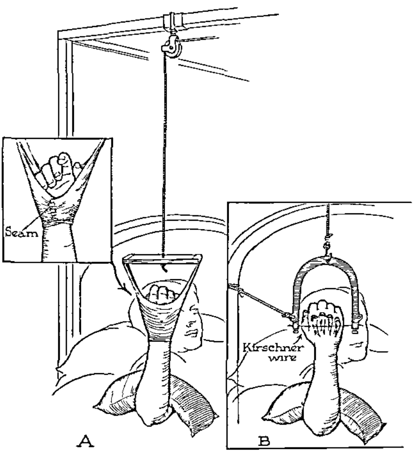


FIG 773 Traction suspension for forearm and Colles' fractures (A) By wrist and hand cuff (B) by Kirschner wire through metacarpal bases

Operative Treatment

In fracture of both bones of the forearm,

if one or both bones are badly comminuted or badly displaced, with the ends caught in the muscles or interosseous membrane, it will sometimes be found impossible to reduce the fracture by any closed method. In such cases open reduction should be performed as soon as this decision can be reached. It should not be delayed beyond ten days, and if the decision as to the necessity for operation can be arrived at before that time it is advantageous. The author believes that if possible the operative procedure should be started on the ulna, and this bone should be firmly reduced and fixed *before the radius is exposed. The* radius is then more easily handled.

In these cases, also, a plate of proper temper and length is preferable. If the fracture is oblique and is not comminuted, sometimes two screws long enough to penetrate both sides of the cortex will suffice instead of a plate. The screws should be exactly the length of the diameter of the bone at the place they are inserted. Screws protruding between the fragments do not add to the probability of good function. The author has found that some form of nonirritating metal, such as vitallium, is best for this purpose Screws of ivory or beef bone must be larger in diameter than the standard metal screws to insure strength; the stronger metal screws can be of smaller diameter than those used in the tibia and femur.

The incision over both radius and ulna should be at a point just lateral to the place where the bone lies closest to the skin. It should not be immediately over the bone, and the plate should be placed beneath the muscles. Care should be taken to follow intermuscular planes, so as not to traumatize muscles or tendons, because the disability is in direct proportion to the amount of damage to these structures which tends to interfere with dexterity in the hand and fingers. The approaches have already been described under fractures of the individual bones (Fig. 772).

It is advisable to fix both bones when operative procedure is resorted to. It is frequently found that if the ulna is first fastened snugly with a plate, the radius is much more easily reduced and held In the author's experience after one bone is fixed the other is much more easily reduced, but it is usually the first bone exposed that is the difficult one to reduce and hold in reduction. After this is accomplished the other responds to manipulation more easily.

In all fractures of the forearm the external immobilization apparatus, whatever it may be, should not extend beyond the *metacarpophalangeal joints. The fingers* should remain exposed and should be exercised regularly. The necessity for exercise should be impressed upon the patient, and even though the muscles are sore the fingers should be kept moving in complete flexion and extension, starting immediately after operation.

Postoperative fixation should be by anterior and posterior board splints supported by plaster, which extends from the metacarpophalangeal joints to the axilla, with no lateral pressure on either radius or ulna. Early motion of the fingers should be encouraged and the immobilization period should be not less than eight weeks.

COLLES' FRACTURE

Under this classification have come to be grouped the fractures of the lower end of the radius, although technically this is an error. Colles' fractures are practically always impacted and not infrequently there is disintegration of cancellous bone structure sufficient to cause shortening Frequently the fragments are so impacted and locked together that no amount of straight traction will suffice to permit proper reduction. It is difficult to obtain perfect relaxation with local anesthesia in these fractures, and complete anesthesia should be induced.

The first move in reduction is to break up the impaction. This should be done thor-

oughly, and the simplest method is to place the thumbs on the dorsal surface of the wrist the ends of the thumbs meeting over the line of fracture With the fingers grasped around the flexor surface of the wrist and hand, the impaction is broken up by levering the fragments backward in the direction which tends to increase the deformity *while concomitant strong traction is made* This manipulation is carried to a point where the fragments are entirely loose and feel more or less like a bag of bones under the skin [Thorough disimpaction of the fragments is of vital importance Many men however prefer another method of accomplishing it because of the tendency theoretically at least of additional damage to the posterior cortex of either fragment by forced dorsiflexion of the lower one The same grasp of the wrist and hand is used and under strong distalward traction rocking and rotation maneuvers are carried out If these fail in disimpacting the fragments the procedure described above is resorted to —Ed]

When this has been accomplished the traction should be directed distalward in line with the long axis of the radius with the thumbs still in the same position When the posterior edges of the fragments have been brought into contact in which volarward pressure on the lower fragment and dorsalward pressure on the upper may help *the wrist should be flexed and inclined toward the ulna* This manipulation brings the fractured surfaces exactly in contact provided there has been enough traction before the fragments are brought into alignment The hand should be fixed in moderate flexion of the wrist with ulnar deviation and held there with either a palmar or dorsal splint of plaster or metal which extends from the elbow to the metacarpophalangeal joints only Active use of fingers elbow, and shoulder should be encouraged from the beginning

A sugar tongs splint is advantageous in some cases to fix these fractures This is simply a plaster mold extending from the metacarpophalangeal joints up the dorsal surface of the hand and arm around the back of the lower end of the humerus and brought down over the flexor surface to the metacarpophalangeal joints

There are other ways to reduce this fracture but if this manipulation is properly carried out a reduction will be obtained in almost every instance If the cancellous bone at the lower end of the radius has been badly damaged by crushing at the time of fracture there may remain some shortening which is impossible to overcome because of actual disintegration of the bone This is especially true in elderly patients If this is sufficient to cause readily discernible lowering of the ulnar head in relation to the radius with disturbance of the lower radioulnar joint relationships the methods described below under comminuted fractures into the wrist joint should be considered and put into use if the attendant circumstances warrant it The risk involved in noncorrection is that of pain on forced supination at the wrist

The reduction should be checked by x ray before plaster is applied in order to determine whether there is any loss of length comparing the levels of the distal ends of radius and ulna and to determine that the lower articular surface of the radius slopes downward and forward at the normal angle *If it is at a right angle to the* long axis of the radius or is directed even slightly dorsalward further flexion of the wrist is indicated

The length of time of immobilization of the fracture depends on the type of fracture with which one is dealing In young individuals where there is almost a transverse fracture a few days of complete immobilization followed by two or three weeks of partial immobilization are frequently sufficient because there is no tendency to displace the bones In elderly individuals where there has been crushing of bone and the ends frequently do not fit together well

it might be justifiable to immobilize them for from three to six weeks. It is the author's opinion that the length of immobilization does not lead to more disability in these cases than does too early motion.

In older people particularly the length of immobilization may depend upon the degree of flexion in which the wrist is placed. That is, if an extreme degree of flexion is necessary to maintain the articular face of the radius in the proper plane, then this position should be changed to a more neutral one in one to two weeks, depending on the tendency to recurrence. To leave the wrist in a position of acute flexion until there is x-ray evidence of bony healing is a certain way to get marked limitation of extension, which will in all probability be permanent. Therefore, the minimum and maximum time of immobilization in Colles' fracture or its modifications is something to be carefully considered.

After-treatment with motion and massage can be started very early if the fragments are supported by someone who knows how they should be supported in order to prevent recurrence of deformity, and if this can be carefully done motion can be started in many cases in from five to ten days with great advantage to the subsequent function of the hand and wrist. This should not be turned over to inexpert hands; it should be done by the surgeon or someone who is *competent*, who has seen the *x*-rays and who knows the individual case.

It is of great advantage to put on a molded plaster splint, held with straps, or two molded plaster splints held in the same way, which can be easily removed by the patient. After the first to the third week, depending on the type of fracture, the patient removes the splint three to six times a day and floats the hand and lower part of the forearm in hot running water, exer*cising the wrist and fingers* with voluntary motion only, allowing the hot water to run directly on the wrist and radius, and increasing the heat gradually. The author has seen no shiny, glossy hands occur when this treatment was applied during the second ten days after a fracture, and continued; nor has he seen any atrophy of the bone which occurs so frequently with long immobilization or too early mobility under adverse circumstances.

Reversed Colles' Fracture

Occasionally a Colles' fracture occurs in reverse and, instead of the lower fragment being displaced backward and upward, it is displaced forward and upward. In such cases the mechanism of reduction should be reversed, and the mechanism of immobilization, instead of bringing the hand downward in flexion and ulnar deviation, should bring it into extension with ulnar deviation, or at least into the midpoint between flexion and extension.

COMMINUTED FRACTURES OF LOWER END OF RADIUS INTO WRIST

These fractures are frequently impacted, the fragments are considerably distorted with the lower end of the radius spread out, and the fracture sometimes extends into the radio-ulnar joint. These cases must be thoroughly disimpacted before reduction can be effected. Frequently it is necessary to maintain traction for as long as two to four weeks, because there is no stable abutment of the fragments and, therefore, the muscles of the forearm which have their insertion in the hand constantly tend to shorten the radius After disimpaction has been thoroughly carried out there are three methods of procedure to maintain traction.

1. A cuff made of half-inch wool felt is carefully molded and sewed around the lower end of the radius and the base of the carpus. The hand is suspended by this cuff to an overhead pulley which carries from six to ten pounds of weight. Counter-traction is made by placing a sandbag across the lower end of the humerus, the extensor surface of the humerus being held to the

bed and the sandbag acting as counter traction It may be necessary, in order to mold the fragments back into position to anesthetize the patient Local anesthesia is of more value in these cases than in impacted Colles' fracture because the anesthetic will filter between the fragments The ligaments extending from the carpus over the lower end of the radius will help greatly in molding the fragments in what frequently amounts to a jigsaw puzzle in the lower end of the radius Traction must be maintained until the fragments are shown by x ray to have become more or less homogeneous and solid enough to withstand the displacing effect of the muscles of the forearm (Fig 773)

2 The traction force may also be applied through a wire inserted through the bases of the second third fourth and fifth metacarpals This is best done under general anesthesia With the patient's hand in pronation, an assistant flattens out the palmar arch of the metacarpal bases and holds the thumb sharply adducted out of the way Through a one eighth inch skin nick the wire is driven from the thumb side directly across through the bases of the metacarpals to emerge on the ulnar side This has advantages over insertion of the wire more distally The wire goes through practically a solid block of cancellous bone instead of through successive hard cortical shafts on the surface of each of which skidding of the wire may occur, and, the bases of the bones being in close apposition, there is no risk of hitting vessels or nerves lying between them as is the case more distally In addition there is no damage possible to lumbricales or interossei The wire and the attached yoke then serve in place of the felt wrist cuff as described above (Fig 773)

3 Instead of the use of the wire traction combined with suspension and counter traction as described above, a fixed traction incorporated in plaster may be used After the wire through the four metacarpal bases has been placed, a second wire is passed through the radius at about its midportion, and manual distraction exerted on the yokes attached to the two wires to regain normal length of the radius While this is maintained by an assistant the fragments can be molded by the surgeon When satisfactory position by fluoroscope or x ray has been obtained, a circular plaster is applied from below the elbow to the metacarpophalangeal junctions, incorporating both wires The manual distraction is maintained until the plaster has hardened enough to firmly hold the wires The proximal wire can be placed through the olecranon process, if so desired Use of the elbow and fingers is thus allowed with fixed maintenance of length, and the patient is made ambulatory

It is extremely important to replace the fragments and maintain them in place until consolidation has taken place, otherwise there will be serious disability of the hand and wrist

After treatment

A circular plaster may be applied in the suspension cases as soon as it is certain that the fragments will not displace The plaster should be carefully molded and should be applied while traction is maintained Semipronation is the position of choice with the cast not extending beyond the metacarpophalangeal joints Under any circumstances early motion of the fingers should be instituted Flexion and extension of the wrist should be started as soon as the fragments are firm enough to warrant it, with the aid of the usual physical therapeutic measures

Immobilization in plaster in these cases is necessarily longer than in the usual lower radius fractures, since the callus is soft and compressible for some time Six to eight weeks is none too long for immobilization for this kind of fracture in this location and there should be x ray evidence of filling in of the defect before support is removed If the double wire fixed in plaster is used, from six to eight weeks is the time usually

needed for retention of the plaster support. Wrist function is slow to return because of adhesions which form between the radius and carpus and the tremendous fibrosis which occurs in the ligaments surrounding the wrist. Long disability is the rule. Three months would be a relatively short disability in this type of fracture and, even with good physical-therapy treatment, it may run much longer and result in some permanent disability.

OBLIQUE FRACTURE OF LOWER END OF RADIUS INTO WRIST JOINT

To the casual observer this appears to be a simple fracture, but when it is remembered that the brachioradialis muscle is inserted in the tip of the radius, it will be seen that relaxation of this muscle and counter-traction to its displacing effect are necessary. Full supination of the hand and strong ulnar deviation with palmar flexion, and fixation in this position with the plaster extending above the elbow, is necessary after reduction in some cases to hold this small fragment in position. This necessitates the use of circular plaster from the metacarpophalangeal junctions to include the elbow flexed at right angles. The fragment becomes fixed in from ten days to three weeks, and when it has come to this stage motion may be started at the wrist joint. Bivalving the plaster is the safest way. It is possible to begin pronation and supination and allow some voluntary flexion if, on manual examination, the fracture seems to be firmly fixed The use of physical therapy may help in this.

Complete removal of plaster should be delayed until the fragment is firmly fixed From four to eight weeks may be necessary, but usually six weeks is sufficient, especially in younger individuals.

DISTORTION OF RADIO-ULNAR JOINT

On the integrity of the radio-ulnar joint depends much of the dexterity of the hand, and if this joint is distorted there is loss of pronation or supination or both The distortion may be caused by fracture of the lower end of the radius into the joint, or by shortening of either the radius or the ulna without comparable shortening of the other bone. The ulna serves as a pivot plane around which the radius rotates at its lower end, and in any injury to the lower end of the radius and ulna this joint should be carefully examined, if only one bone is fractured, the joint should be examined to determine its integrity. If there has been shortening of the radius without shortening of the ulna following fracture, the ligaments of this joint are almost certain to have been injured, and if the joint surfaces are not properly replaced and held in position the supporting ligaments will not hold them after healing. This results in a very weak hand and wrist

In a case of distortion injury a felt pad should be placed laterally on the ulna and one on the radius These pads should not meet over the flexor or extensor surfaces, but the radius and ulna should be bound firmly together, preferably with adhesive tape, prior to the application of the plaster and immobilization of the fracture. This cannot be done, however, until the fracture has been reduced.

Late repair of rupture of the ligaments supporting the radio-ulnar joint is unsatisfactory. The joint can be supported by a loop of fascia fastened around the ulna, crossed over the dorsum of the hand and brought back through the radius, and fastened again anteriorly over the radio-ulnar joint The author has never seen a case, however, that did not have some permanent disability after this operation, although it strengthens the joint to some extent, it does not establish a complete cure. [Ulnar head resection, subperiosteal, uniformly relieves these cases. It is described below under disruption of the inferior radio-ulnar joint.—Ed.]

UNUNITED FRACTURE OF BONES OF FOREARM

In ununited fracture of one or both bones a bone graft applied in a way that will thoroughly immobilize the fragments and hold them in position is imperative The choice as to the type of graft should be based almost entirely on its ability to produce effective immobilization It has been the author s experience that a heavy onlay graft meets the requirements better than any other type The bones of the forearm are small in diameter and an inlay graft has to be too small and therefore too fragile to maintain the position of the fragments against the pull of the muscles

When the ends of the fragments have been prepared equalized in length and brought into proper rotation and alignment they should be held in this position with clamps of proper size and shape to conform to the curves of the radius and ulna After the fragments are firmly fixed by these clamps it will be found that placing the graft on the dorsum of both radius and ulna is easiest from the standpoint of the operator A flat surface should be made on one side of each bone with an abutment at each end against which the ends of the graft will fit The abutment surface should be at a right angle to the long axis of the bone The graft should be measured to the smallest fraction of an inch to fit perfectly between the two end abutments An attempt should be made to put it where it will not come immediately in contact with the line of incision on the skin otherwise it makes little difference where it is placed so long as it is tight and stays that way It should then be screwed firmly in place with at least two screws in each fragment placed at angles to each other in order to withstand the torque as well as the angulating effect of the muscles (Fig 774)

After treatment

A long period of immobilization is necessary The position of immobilization should be decided at the time of operation It depends on the amount of contracture and the group of muscles most contracted as to which position is most advantageous In the author s opinion no rule can be made for ununited or malunited fractures because the stress varies tremendously in each case The plaster should be flattened from front to back that is from flexor surface to extensor surface and should not be changed without due cause Frequent changing of

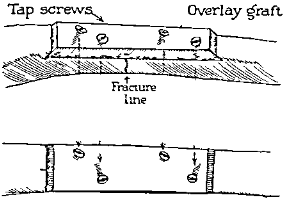


Fig 774 Overlay graft for forearm bones Note counter sunk beveled ends and varied directions of fixing screws

plaster and manipulation of fragments is in his opinion responsible for more non unions than any other one factor Three months immobilization is none too long and it is not uncommon to have from six months to a year s disability following non union of both bones of the forearm

In cases of nonunion with serious deformity the author has sometimes found it necessary to use traction by Kirschner wires in the upper and lower fragments especially in the radius to overcome part of the deformity by stretching the soft parts prior to operation Otherwise the fragments will be dragged back into deformity after operation simply by the pull of the contracted soft parts

MALUNITED FRACTURES OF FOREARM

There is probably no other operation on

the skeleton that offers more difficulty than the replacement of fragments in malunited fracture of the forearm. The soft parts are usually badly contracted, and the muscles which displace the fragments toward each other are short and strong, and offer serious difficulty to replacement of the fragments and to maintaining them in proper reduction. Inasmuch as malunion is usually due to failure of whatever treatment has been used to withstand the pull of these muscles, it can be understood that overcoming the pull of the muscles once they are contracted offers even more difficulty after such malunion.

As noted before, the bones of the forearm are small in diameter, and after a long period of disuse they become very fragile. Strong applied force may break the ends of the fragments and great care should be taken to avoid this in the application of clamps and in their manipulation. It is necessary to free the bones completely from their muscle attachments in order to replace them. Excess callus must be entirely eradicated and the ends of the fragments must be restored as nearly as possible to their normal contour. If they can be brought into line a steel plate applied to each bone in accordance with the technic previously described is frequently the most satisfactory method of maintaining reduction, if it can be used. If it cannot, wiring or other forms of relative fixation will have to be utilized.

After-treatment

The arm should be carefully immobilized in a snug circular plaster, as after operation for nonunion, and checked frequently by x-ray to determine whether or not the deformity is recurring If it is, the patient should be put to bed and traction and counter-traction applied with the arm in suspension, by the methods previously described. In some cases the author has had to resort to placing a wire through the radius above and below the fracture, maintaining extension and counter-extension through the wire in order to prevent recurrence of angular deformity, either in suspension or by incorporation of the wires in the plaster.

The period of immobilization in these cases is usually not less than three months—sometimes six to nine months The circulation is poor, because as a rule the arm has been immobilized previously for a long time. There is much fibrosis, and yet it is impossible to remove the immobilization for physical therapy. The patient should be encouraged to move the fingers, not just wiggle them.

The care is the same as that for nonunion or simple fracture of both bones, except that it must be continued for a longer period. The prognosis as to disability is not the brightest. There is usually limitation of pronation and supination, and frequently considerable limitation of muscle strength and flexibility in the hand and wrist.

If the fragments have been angulated and overlapped it will be necessary to do one of two things in many instances: (1) Shorten the bones to meet the already contracted condition of the soft tissues of the forearm, the muscles and fascia, or (2) free the ends of the fragments, clean them off and insert wire or pins above and below the fracture line, close the wound and return the arm to traction until such time as these tissues can be stretched If this is not done, and an attempt is made to pry these fragments back by leverage, it will be found that the soft tissues cannot be stretched sufficiently to allow proper replacement; or, if they are successfully replaced, they will angulate out of place in spite of almost any retention apparatus which can be put into them or on them.

It is advisable in these cases to use plates, with six instead of four screws if possible. Bone grafts of any type are too brittle and too small to retain the fragments in position They may fracture as a result of the pull of the muscles, and usually fracture

at the site of the drill holes made through the graft to maintain it in position A thin strong plate with machine screws penetrating both cortices is the strongest form of retention apparatus with which the author is familiar This may be supplemented by an osteoperiosteal graft wrapped around the site of the fracture An overlay graft if it could be made strong enough would be ideal but when this is attempted it will be found that the incision can hardly be closed because of the lack of elasticity of the soft tissues and the fact that the volume of bone has been increased to a point where the tissues will not stretch over it

There is one condition which may result as a consequence of shortening of the radius without commensurate shortening of the ulna This is a lowering of the ulnar head with consequent disruption of the radio ulnar joint and this causes pain at the wrist on forced rotation especially supination The radius rotates around the ulna at its lower end and if the arc these two bones work on is disrupted by the change in length the result will be serious disability in the hand because of pain and loss of dexterity It is frequently impossible to restore the length of the radius and therefore subperiosteal resection of the lower end of the ulna has been advised In cases where there is serious disability so far as dexterity is concerned and especially if the patient does not have to do heavy work resection of the ulnar head is advisable

The incision should be made on the dorsolateral angle over the ulna the periosteum split the carpo ulnar ligament dissected from the end of the bone and the bone removed from inside its periosteum Active motion should be instituted immediately postoperative This allows the radius to turn freely but is said to interfere at times with the strength of pronation and supination especially the latter In a large majority of cases however the pain caused by the disruption of the joint will be relieved [When the lower ulna has been subperiosteally separated the styloid process may be cut across at the ulnar base inside the periosteal tube and left behind with the attached ulnar collateral ligament The shaft of the ulna should be sectioned obliquely from above downward and toward the radius so as to leave a smooth beveled surface on the ulnar side instead of a sharp edge No more than three quarters inch to one inch of ulna should be resected —Ed]

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33

Fractures and Dislocations of Carpus

D. W. GORDON MURRAY, M.D.

FRACTURES OF CARPUS

FRACTURE OF SCAPHOID (NAVICULAR)

The carpal scaphoid (navicular) is fractured more frequently than any other bone of this group. It may be complicated by Colles' or other fractures. Because each group of fractures presents a distinctly different problem they may be classified as follows: (1) Of the tuberosity, (2) of the waist, and (3) of the proximal third.

The exact position of these fractures may vary considerably but the principles of treatment in any one group are not changed by slight variations of position of the individual fracture.

Recent Fracture of Tuberosity. This fracture rarely involves the radial articular facet of the navicular. It varies in character from a small chip of bone off the tip of the tuberosity to a more extensive fracture involving the distal third of the bone. In any of these, if seen within two to three weeks of the time of fracture, adequate fixation in a skin-tight plaster extending from the interphalangeal joint of the thumb to the elbow with the wrist in normal dorsiflexion will give satisfactory union (Fig 775). The fragments are rarely displaced, so that manipulation is usually unnecessary. If the fracture involves that part of the tuberosity to which the radial collateral ligament is attached and the fragments are displaced, the displacement should be corrected by manipulation and the type of fixation described above should be applied Because of the good blood supply to this area these fractures unite more quickly than those occurring more proximally in the bone, and fixation for periods varying between four and six weeks is adequate. [Nonunion in this part of the bone is practically unknown.—Ed.]

Recent Fracture Through Waist of Bone. This fracture (Fig. 776) occurs at the narrow part of the bone, which varies in position in different scaphoids depending on the special shape of the bone, some being long and slender, others short and thick. It occurs more commonly than the others. Occasionally there is moderate displacement, but frequently there is none. As this fracture involves the radial and capitate articular facets, it is necessary to correct any displacements that may be present. This can easily be done under the fluoroscopic screen, when the position which corrects the relationship of the fragments can be selected. Normal dorsiflexion (the position into which the wrist goes when the fist is firmly clenched) will usually correct the deformity. Radial deviation of the hand is sometimes necessary to correct a tendency of the fragments to gape at the fracture line.

In the average case the diagnosis of fracture through this part of the scaphoid is made by x-rays taken in the oblique position. The ordinary anteroposterior and lateral x-rays taken for wrist injuries may fail to show this fracture in its early stages

Not until fairly extensive rarefaction has occurred (Preiser's disease[11]) a few weeks or months later, will it be picked up readily on the ordinary anterposterior and lateral plates It is advisable therefore when there is any suspicion of injury to the carpus or where the anteroposterior and lateral plates are negative and the patient has persistent hands[10 23] The importance of early diagnosis cannot be overemphasized because if diagnosed and treated adequately soon after the fracture has occurred all these fractures unite satisfactorily If however the diagnosis has not been made and the fracture is allowed to progress until absorption of bone and cystic changes have oc

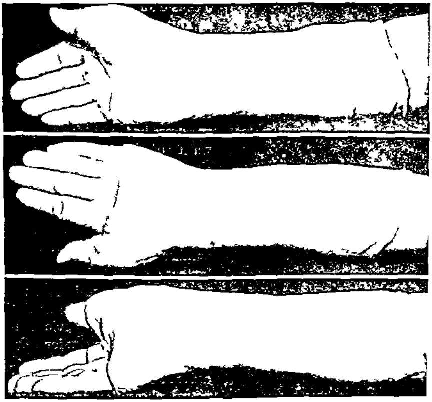


FIG 775 Plaster encasement for fracture of carpal scaphoid (*Top*) Ventral (*Center*) dorsal (*Bottom*) oblique Note molding to palm and forearm upper and lower limits moderate grasp position of wrist and inclusion of abducted proximal phalanx of thumb

symptoms over the radial side of the carpus to have further x rays made in special positions These positions are (1) With the ulnar side of the hand on the plate the dorsum of the wrist should be at an angle of 45° to the horizontal and (2) with the patient lying on the face the first and second metacarpals should be flat on the plate The possibility of a bi partite bone must be kept in mind in making the diagnosis as it occurs in 0 25 per cent of all curred the fracture may take many months to unite even with adequate fixation or it may fail to unite even with prolonged fixation

FIXATION The fixation of this fracture is similar to that described for fracture of the tuberosity The splint must prevent all motion of the proximal phalanx of the thumb the first metacarpal and the wrist joint Some fractures of the scaphoid go on to nonunion even though the wrist has been

supported in plaster, but in these cases the plaster has failed to control the motion of the first metacarpal. Another source of inadequate fixation in these cases is failure to carry the circular plaster more than a short distance up the forearm. It should extend to just distal to the elbow crease in order to get maxim'.m immobilization. Any

FIG 776. Recent fracture through midportion of carpal scaphoid

motion is transmitted through the trapezium to the distal fragment of the scaphoid thereby providing one of the conditions which may cause nonunion.

While some fractures in young patients may unite in six weeks with adequate fixation, as a general rule fixation should be continued for not less than eight weeks, and before the splinting is discontinued there should be radiologic evidence of union of the fracture.

Recent Fracture of Proximal Third of Scaphoid. Fortunately this fracture is less common than the others as it presents special difficulties. As shown by Obletz,[22] the blood supply of the scaphoid reaches the bone through the tuberosity and ligamentous attachments. He has shown that in 13 per cent no blood supply enters the bone proximal to its midportion Therefore, a fracture occurring through the proximal third may cut off all the blood supply to the proximal fragment. This, of course, adds a considerable hazard for spontaneous union at this site. If the fracture is recognized early and adequate fixation is provided, most of these fractures unite. This fixation will take not less than eight weeks and should be continued for a longer period if the radiologic evidence of union is doubtful, as described for fractures through the waist of bone. However, regardless of the excellence of treatment, this fracture more commonly than the others may go on to nonunion. At the end of eight weeks the plaster gauntlet is removed, and if radiologic evidence of union is not apparent another gauntlet should be applied for a further period of eight weeks. If, at the end of this time, there is still no evidence of union by x-ray, or if actual absorption or cystic changes are obvious, the case falls into the group of nonunions discussed below. [Bohler and others believe that this procedure should be repeated, in the absence of actual absorption or cystic change, for a period of six months or longer before nonunion is diagnosed The editor is inclined to agree with the present author's concept —Ed.]

AFTER-TREATMENT. During the wearing of the plaster gauntlet in these cases the patient should be encouraged and urged to exercise all the use of the extremity possible. This is perfectly safe if the gauntlet immobilizes the proximal phalanx of the thumb and extends to the elbow crease

Following the removal of the gauntlet and with x-ray evidence of union, active use of the wrist is instituted aided by physical therapy. Occupational therapy entailing exercise of the wrist and fingers may aid

the regaining of active use, and heat, massage, whirlpool bath and supervised resisted and guided exercise of the fingers, wrist and forearm may be of help The essential feature of the treatment after removal of the gauntlet is however, increasing active use of the whole extremity in normal activities

DISABILITY As in all injury cases, numerous individual variants determine the length of disability time in the individual case As an 'average figure, however, the case that has been immobilized for eight weeks can expect to return to light work in 12 to 14 weeks from the time of injury, and to heavy laborious work 16 weeks from the time of injury

Under this method of treatment, assuming that the case gets adequate care within the first two weeks of injury, nonunion in the distal third almost never occurs, is seen in not more than 5 per cent of the central fractures and in not more than 20 per cent of the proximal third fractures There are no criteria except the location of the fracture and the time at which treatment is undertaken to guide one in a prognosis as to nonunion

Nonunion of Fracture of Scaphoid If a fractured scaphoid especially of the middle and proximal thirds has not been recognized and has not been splinted, it probably will go on to nonunion It is impossible to know what proportion of these fractures may unite spontaneously without treatment However, there still remains a large number of wrist injuries resulting in nonunion of fractured scaphoids If the fracture shows no radiologic evidence of union at the end of four months with or without treatment, especially if there is beginning absorption and cystic change in the bone with possibly some sclerosis surrounding this, it is unlikely that fixation at this stage would allow union to take place within several months and it is certain that many of them will never unite with splinting alone If first seen within two months of the occurrence of the fracture, a test of splinting for two or three months may be tried, and many will unite with this form of treatment

When, by these criteria, a definite nonunion is considered established the most certain method of insuring union of the

FIG 777 Graft for nonunion of proximal third of carpal scaphoid (*Top*) Before operation, (*Bottom*) late result

fracture in the shortest possible time is by bone grafting A peg is inserted through the tuberosity across the fracture line and into the proximal fragment as described by the author[30] Drilling alone, as described by

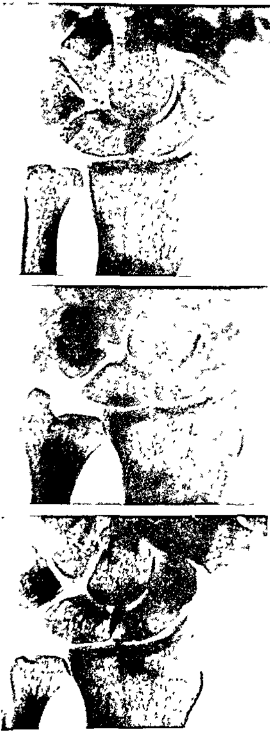


FIG 778 Graft for nonunion of distal third of carpal scaphoid· (*Top*) Before operation, (*Center*) postoperative; (*Bottom*) result at nine years—no arthritis.

Beck and used by many others, is followed by union in a proportion of the cases, but when the fragments have been drilled the insertion of the graft adds very little to the difficulty or time of the operation and the certainty of the result is greatly increased (Figs. 777 and 778).

Bone Graft of Scaphoid. The operation is greatly facilitated throughout by placing the radial side of the wrist uppermost with the ulnar side resting on a sandbag, and the wrist held in full ulnar deviation (Fig 779). This position brings the tuberosity of the scaphoid, the point of approach, to the surface, lying as a prominence beneath the skin. The operation is carried out through a short curved incision over the anatomic snuffbox. The curved central part of the incision lies over the abductor pollicis longus tendon, providing easy access to the tuberosity and allowing for the oblique approach of the drill since it must lie in the direction of the long axis of the scaphoid The extensor brevis and abductor pollicis tendons are retracted toward the volar surface of the wrist The extensor pollicis longus and extensor carpi radialis longior and brevior are retracted toward the dorsal surface. The cutaneous branches of the radial nerve are protected and retracted with the latter tendons. The radial vessels passing obliquely through the volar and distal aspects of the anatomic snuffbox are gently retracted with the abductors of the thumb This exposes the radial collateral ligament of the wrist joint and the tuberosity of the scaphoid The dorsal capsule of the wrist joint and the adjacent collateral ligament are divided, exposing the distal third of the radial facet of the scaphoid. The common fracture through the waist of the bone, for which the operation is usually performed, is seen without difficulty lying at, or slightly distal to, the styloid process of the radius. Fractures of the proximal third lie more under cover of the styloid process and articular facet of the radius, but can also be seen without difficulty through

this opening if the wrist is kept in marked ulnar deviation

In cases only a few months old, the fracture appears as a fine line crossing the radial facet The cartilage appears normal in all respects In older cases the cartilage

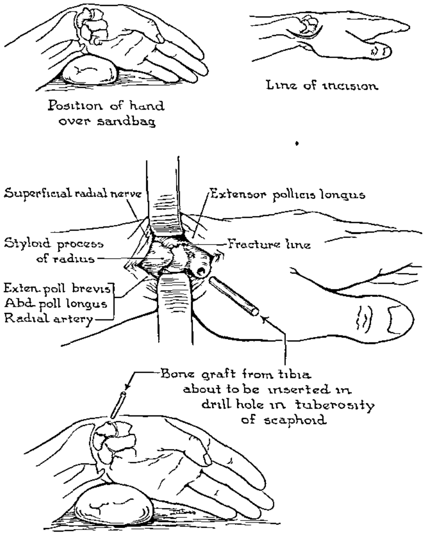


FIG 779 Operation for bone graft of carpal scaphoid

is less healthy and the space at the fracture line may be wider In still older cases definite arthritic changes in both the scaphoid and lower end of radius are obvious in addition to absorption at the fracture line

With the fracture line under direct vision, movements of the wrist joint will demonstrate motion between the fragments if there is nonunion of the fracture In some cases, forcible ulnar deviation will separate the fragments quite widely

If there is any displacement of fragments, a thin elevator curved to fit the radial facet is applied to the proximal fragment to bring it into good position The fracture surface usually is not disturbed A small notch is made in the tuberosity of the scaphoid so that a drill will start without difficulty Selecting a drill from three sixteenths to one quarter of an inch in diameter, a hole is made from this notch in the tuberosity along the long axis of the scaphoid crossing the fracture line and passing into the proximal fragment to a point just short of the

articular cartilage at its tip. During this drilling operation the fragments must be held in accurate alignment, otherwise the deformity will be maintained permanently by the graft The depth of the drill hole may be followed by removing the drill at intervals and using a probe as a measuring stick, comparing the depth of the hole with the length of the bone as measured on its

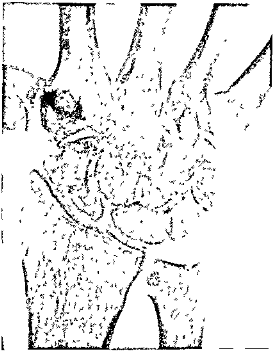


FIG 780 Untreated nonunion of carpal scaphoid Note arthritis of wrist joint, elongation of radial styloid, and degeneration of scaphoid fragments

surface. Bone from any source may be used for the graft but the strongest and best bone may be obtained from the subcutaneous surface of the tibia. A small bar of this may be removed by motor saw and is shaped by shaving it with a chisel. It is driven home in the drill hole and cut short so that it does not project above the level of the tuberosity. The fragments are then firmly impacted to make sure that the driving of the graft has not separated the fracture surfaces. The ligaments are repaired, the skin is closed without drainage, dressings are applied, and a loose comfortable plaster cast is applied to support the thumb and wrist

Ten days later this plaster is cut off, the stitches are removed, and a skin-tight circular plaster, the type already described under recent fractures, is applied, reaching from the interphalangeal joint of the thumb to the elbow. The stitches are removed from the leg and a plaster applied from the ankle to the knee and the patient allowed to bear weight. This latter plaster is left on eight weeks. The support of the wrist is maintained for ten weeks At this time it is removed and x-rays made If there is radiologic evidence of union of the fracture with both fragments viable and the bone graft united to both fragments, the wrist is left without support and the after-care described for the united case is instituted. In most cases of fracture of less than one year's duration, union has taken place at this time. If, however, there is any doubt regarding union, similar support is supplied for another month when further x-rays are made

In fractures through the proximal third, not infrequently the x-rays show aseptic necrosis of the proximal fragment This requires more prolonged postoperative fixation to allow for revascularization of this fragment. In ten cases of this nature treated by this method by the author, revascularization and union took place in all In some of these it was necessary to continue the support for periods up to four months. It will be obvious also that it is more difficult to place a graft accurately in a small proximal fragment than in other fractures The operation for bone grafting was carried out successfully without complications by the author in 50 cases. Solid union by bone occurred in all but two. Against advice, both of these patients removed their plaster splints and returned to work within a few weeks. One was reoperated upon and subsequently united firmly by bone The other patient has not returned for operation. In these 50 cases, the functional results were

95 per cent if the fracture was not complicated by other injuries, and the economic results in the same group were 100 per cent.[29]

Old Ununited Fracture When a fracture has been ununited for a long period, wrist joint and attempts at bone grafting are not advisable (Fig 780).

In this stage of extensive arthritis, there is great disability in the wrist joint from pain, swelling, limitation of motion, and weakness of the grip Many of these pa-

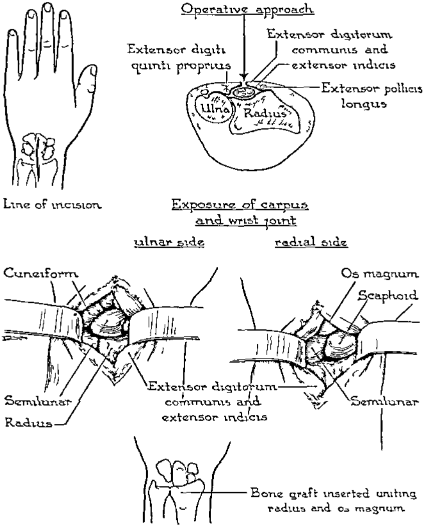


FIG 781 Exposure for operations on dorsum of carpus

the absorptive changes (Preiser's disease[11a]) become complicated by arthritic changes at the fracture site, in the radial articular surfaces of both fragments of the scaphoid, and in the articular facet of the lower end of the radius Secondary arthritic outgrowths of bone appear on all these surfaces and the styloid process of the radius becomes elongated. In these cases the symptoms are those of arthritis of the tients are improved considerably by excision of both fragments of the scaphoid.[2, 16, 24] None regain normal function of the joint, neither are they completely relieved of pain following this procedure However, in many cases there is enough improvement to warrant the operation Fig 781 shows the approach for excision

If, in spite of excision of the scaphoid or in the presence of marked arthritis without

excision, the wrist has much impairment of function and remains painful, the best prospects for improved function of the hand with relief of pain are provided by an arthrodesis of the wrist joint.

Arthrodesis of Wrist Joint. The operation is best carried out with a pneumatic tourniquet around the upper arm A midline dorsal incision three inches in length is made, extending from the base of the third metacarpal upward to a point one inch proximal to the distal end of the radius. The posterior annular ligament is divided at both the ulnar and radial margins of the common extensor group of tendons. The periosteum and tendon sheaths of this group are separated from the dorsal aspect of the lower end of the radius extending upward for about three-quarters of an inch from the level of the wrist joint. This allows approach to both the radial and ulnar halves of the wrist and carpal regions, by retracting the common extensor tendons and their sheaths either medially or laterally (Fig. 781).

As the operation is usually done for a lesion which has mostly destroyed or devitalized either the scaphoid or the semilunar bones, it is best to remove the semilunar, the devitalized proximal fragments of the scaphoid, and the cuneiform, leaving the pisiform undisturbed. With osteotomes and gouges the articular cartilage and a very thin layer of subjacent bone are removed from the facet of the lower end of radius. The attachment of the base of the triangular fibrocartilage to the ulnar margin of the radius and the cartilage itself are left undisturbed The articular cartilage of the radial facet of the scaphoid and of the head of the os magnum is completely removed. That of the unciform is left undisturbed as it lies opposite the triangular fibrocartilage covering the distal end of ulna. By this means the carpus becomes fused to the lower end of radius but the ulna is not involved so that pronation and supination of the hand are not interfered with The osseous surfaces so prepared should be shaped so that the maximum bony contact will be obtained with the wrist in about 30° extension

With a quarter-inch bit, three holes are drilled proximally from the distal articular end of the radius extending about one and a quarter inches into the lower cancellous end of the shaft. The septa of cancellous bone between these holes are easily broken down, forming a single mortise one and a quarter inches by three-quarters of an inch by one-quarter of an inch. With the same bit three holes are drilled into the os magnum and remaining portion of the scaphoid and a mortise one-half inch in depth by three-quarters of an inch in width and a quarter of an inch in thickness is formed The direction of this mortise in the carpus should be placed so that it is in line with the mortise of the lower end of radius when the wrist is in 30° extension but with no deviation to either the radial or the ulnar sides. With a motor saw a bar of bone one and three quarters of an inch in length by three-quarters of an inch in width is removed from the subcutaneous surface of the upper third of tibia. When this has been trimmed accurately to this shape, one end is driven into the mortise in the lower end of radius, fixing it very firmly in this bone By traction and manipulation the distal end of the graft is worked into the mortise in the carpus.

Care must be taken to be sure that the graft is not too long, or the carpus and lower end of radius will be kept from coming into contact. If properly fitted, this graft holds the carpus in accurate relationship to the lower end of radius and no other internal fixation in the way of screws, plates, wires, sutures, etc., is required. Some small chips of bone may be added to the area surrounding the junction of the carpus and radius The soft tissues on the dorsum of the wrist are repaired. A circular plaster is applied from the metacarpophalangeal joints to the axilla with the elbow in right-angle flexion.

While the plaster is drying and being molded into shape longitudinal pressure is applied to the metacarpus to make sure that the osseous surfaces of the wrist region are kept in contact

In doing the operation one must be mindful of the presence of the flexor tendons and median and ulnar nerves on the flexor surface of the wrist and must protect them from injury by sharp instruments [For other technics for wrist fusion see Chapters 14 and 15 —Ed]

This operation results in shortening of the wrist The deformity, however is very slight and is not objectionable The resulting slackness of the extensor and flexor tendons is compensated for and within a few days a full range of motion of the digits can be carried out and should be encouraged all through convalescence

After two weeks the plaster is removed and the stitches taken out If x rays at this time show that the alignment is not ideal the necessary correction can be made A skin tight plaster is then applied from the metacarpophalangeal joints of the fingers and thumb to the axilla with a strong loop of plaster passing from front to back between the thumb and index metacarpals holding the hand in a midposition between pronation and supination This second plaster encasement is worn for 12 weeks The plaster is then removed and the wrist x rayed for evidence of bony arthrodesis If this is not yet definite the plaster should be replaced for another six weeks

When bony arthrodesis is evident by x ray, the same after treatment as advised for fracture of the scaphoid should be carried out It is essential that frequent active exercise of the fingers and the shoulder be practiced while the plaster is being worn

The functional and cosmetic results following this operation are excellent (Fig 782) A stable and painless wrist joint capable of hard labor can be confidently expected

Fracture of Semilunar (Lunate)

This bone is fractured less frequently than the scaphoid There is a similarity, however, to the latter bone in that fractures are frequently missed in x rays taken soon after the injury and are recognized only by

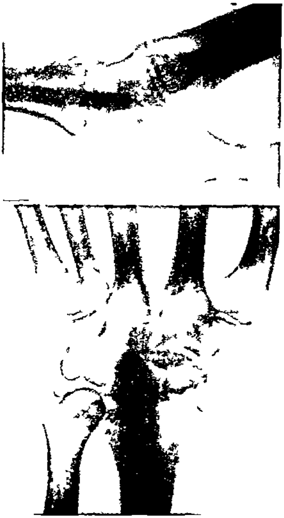


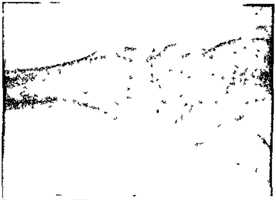
Fig 782 Late result of wrist arthrodesis (*Top*) lateral view (*Bottom*) anteroposterior view

persisting soreness and stiffness of the wrist and by degenerative changes which are apt to follow as demonstrated by x ray examination

Fracture of Cornua

Posterior Horn Small sprain fractures occur involving the posterior horn A good

lateral x-ray is necessary to demonstrate this fracture (Fig. 783). Frequently there is little displacement. The wrist should be splinted in a cocked-up position for three weeks and then light active and passive motion begun. The unpleasant complication of elongation and overgrowth of this posterior horn following this injury may produce stiffness of the wrist and limitation of extension. Occasionally this hypertrophied horn will impinge on the posterior margin of the inferior radial facet, causing limitation of motion and pain Under these conditions, function may be improved somewhat by excision of this elongated horn. If the condition has existed for a considerable time the ensuing arthritic changes may prevent the return of function following the operation.



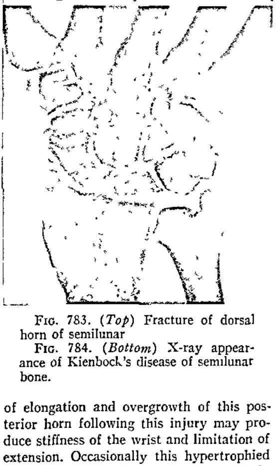


FIG. 783. (*Top*) Fracture of dorsal horn of semilunar

FIG. 784. (*Bottom*) X-ray appearance of Kienbock's disease of semilunar bone.

Fracture of this horn is an evidence in some cases of anterior subluxation of the semilunar bone with spontaneous reduction. The resulting damage to blood supply of the bone may be so extensive that subsequent degenerative changes may occur This should always be kept in mind in considering the prognosis.

Fracture of Anterior Horn. These occur less frequently than fractures of the posterior horn and are usually the result of crushing injuries. They are apt to be complicated by other injuries in the carpus. Splinting should be carried out for three weeks followed by active and passive motion.

Fracture of Body. These are usually fissure fractures running transversely through the bone. They may be complicated by fractures extending into or separating off one or both cornua In severe crushing injuries, comminution may occur. Again, these fractures are apt to be missed in x-rays taken soon after the accident and not until the degenerative changes[13] make their appearance is the evidence of a fracture found.

TREATMENT. If a fissure fracture without displacement is recognized early, splinting in a skin-tight plaster with the hand in a cocked-up position should be carried out for not less than six weeks If at the end of this time x-rays do not show the fracture united, or if there are absorptive changes, the splinting should be continued until revascularization, calcification, and union of the fracture occur. After healing has occurred, and the splinting is removed, the same aftercare as previously described for scaphoid fractures should be followed out.

Aseptic Necrosis. While some of these

fractures probably heal spontaneously with out treatment a certain proportion go on to degenerative changes (Fig 784) This gives an x ray appearance of rarefaction in some areas and condensation of others Later on the bone collapses so that the height of the body may be reduced from any fraction down to a quarter of the orig inal The bone becomes elongated antero posteriorly giving the impression that some of the central part has been squeezed out to cau e enlargement and elongation of the ends and horns of the bone and usu ally shows marked sclero is at this stage The presence of an ununited fracture or marked comminution may be identified in some cases at this stage (Kienbock s dis ease[11a]) At a later period arthritic changes involving the adjacent carpal bones and wrist joint make their appearance causing pain and di ability

Treatment There is no method of re construction or repair of a fully developed Kienbock s disease of this nature If there are no arthritic changes excision of the semilunar bone alone will give a moderate improvement of function of the wrist

Operation The operation is carried out through a dorsal incision reflecting the ex tensor communis digitorum and extensor minimi digiti tendons to the radial side without opening their tendon sheaths The dorsal ligaments of the wrist are divided The bone is usually removed in fragments which readily become detached from each other The most difficult part of the pro cedure is the removal of the anterior mass and horn This may be done with a hook and elevator using some sharp dissection The space between the radius and the head of the os magnum through which the ap proach is made may be enlarged by traction on the middle fingers of the hand Care must be taken with sharp dissection to avoid injury to the structures on the flexor surface of the wrist such as the flexor ten dons and the median and ulnar nerves If the scaphoid has been damaged as well removal of all the proximal row of the carpus except the pisiform gives a fairly useful functional result (Fig 781)

If marked arthritic changes have devel oped causing destruction of the cartilage of the scaphoid and semilunar and of the in ferior radial facet an arthrodesis of the wrist joint should be carried out (See under Fracture of Scaphoid)

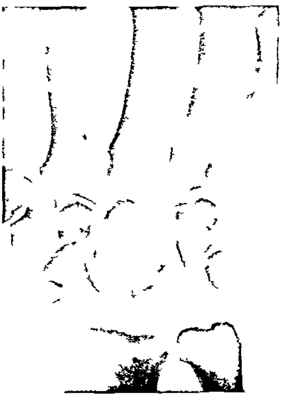


Fig 785 Fracture of cuneiform

Fracture of Cuneiform (Triquetrum)

Fractures of this bone are infrequent (Fig 785) compared with the others in the proximal row of the carpus They are usu ally produced by direct violence[3] and con sequently are apt to vary from small chips off the bone to severe comminution Often they are complicated by severe injuries to other carpal bones If there is little d s placement of the fragments splinting for four weeks u ually allows union to take place Removal of the splinting is followed by the u ual after treatment as described

ofore. If union is attained in this time, no degenerative change occurs, the disy time for light work is about 8 weeks 'or laborious work is about 12 weeks casionally absorptive changes in the occur following these injuries. If there 'ere comminution with great displace- or if absorptive changes have allowed one to collapse, excision is advisable is carried out through a dorsal incision d so that the extensor communis rum is reflected in its tendon sheath, radial side. When the bone has been ed the articular cartilage of the rm is seen in the depths of the remainvity. The pisiform is left undisturbed wing the excision of the bone the wrist d be immobilized until the soft-part d is healed, and then should be mod with the aid of physical therapy vised for other wrist injuries.

Fracture of Trapezium

se fractures are usually of the comon type resulting in multiple fissures gh bone. If there is but little displace- splinting for four weeks will usually le union. A skin-tight plaster should plied from the interphalangeal joint thumb extending around the palm of and and over the wrist and up to the so that motion of the first metal is prevented.

vertical fractures, if the radial half is y displaced, open reduction should be taken. The fragments are replaced ither pinned together or sutured with t. Splinting should be continued for eeks following this operation. Degene and absorptive changes are less to occur than in the bones of the nal row of the carpus. These fractures to unite, and nonunion is rare. The ge disability time for light work is eks, and for laborious work is about 16 s.

hough nonunion is unusual here, when s occur the bone must be preserved because of its important function in supporting the base of the first metacarpal, and its important relationship to the tendon of the flexor carpi radialis Open reduction, clearing the fracture surfaces, and suturing of the fragments together with fine stainless-steel wire will suffice in the simpler cases Where there is great destruction of the bone, the fragments should be pegged together with autogenous bone grafts placed in drill holes.

Fracture of Trapezoid

These occur slightly less frequently than in the trapezium. They tend to be of the compression type and rarely is there great displacement. Fixation in plaster for four weeks usually provides union. Removal of plaster is followed by the usual after-treatment.

When extensive comminution of this bone and the trapezium occur, causing great distortion of adjacent joints with arthritis and pain, arthrodesis between these bones and the distal end of the scaphoid provides the best prospect for an improvement of function.

The average disability time for light work is 10 weeks, and for heavy work is 12 weeks.

Fracture of Os Magnum (Capitate)

Fracture of this bone occurs through the neck and this may be complicated by comminution of the distal end of the bone. It is frequently complicated by other carpal injuries such as midcarpal dislocation with fracture of the scaphoid, etc, in which case the treatment is part of the general procedure of reduction of dislocations and injuries of adjacent bones The distal fragment of the os magnum is usually displaced dorsally in relation to the head. This evidence is best obtained from a lateral x-ray of the carpus. In recent fractures, closed reduction by traction on the index and middle fingers and manipulation may restore the fragments to good position. As

ne head of this bone is covered with artic-
lar cartilage with no ligamentous attachments except at the neck, a fracture through the neck frequently interferes with the blood supply and aseptic necrosis is apt to occur For that reason prolonged splinting necessary in some cases to allow revascularization and calcification of the head

The average case should be placed in a skin tight plaster from the metacarpophalangeal joints to the elbow with the wrist straight or in slight dorsal flexion for eight weeks X rays should be made at this interval If there is evidence of aseptic necrosis, the splinting should be continued until evidence of revascularization has occurred This has taken as long as five months in some cases On no occasion has recent fracture failed to unite when watched and treated in this way The functional results following the usual after treatment have been fairly satisfactory, although there has been moderate restriction of the extremes of motion in all cases

Where no aseptic necrosis has occurred the average disability time for light work is 10 weeks, and for heavy work is 12 weeks

In late cases which have not been recognized and where other fractures and dislocations have persisted for several months, reduction has not been possible except by open operation These fractures will be given further consideration under the section on dislocations (See Dislocation of Midcarpal Joint)

Slight fissure fractures of the distal end of the os magnum without displacement should be supported from three to four weeks at which time union should have taken place and an excellent functional result may be expected The disability time should not be more than five to eight weeks, depending upon the type of work involved

Fracture of Unciform (Hamate)

Fractures of the unciform are usually fissure or compression fractures of the body or fractures across the base of the unciform process These latter occur infrequently There is usually not much displacement of fragments, in which case fixation for four weeks in a skin tight plaster from the metacarpophalangeal joints to the elbow with the hand in slight dorsiflexion is sufficient to provide union The removal of the plaster is followed by the usual active motion and physical therapy regime, and the total disability time should be from 8 to 10 weeks, dependent upon the type of the patient's work

When the unciform process is fractured it may be displaced a moderate amount toward the radial side Rarely can the position of the fragments be improved by manipulation from the surface The process usually unites by fibrous tissue, but as the process does not take a part in articulating surfaces, there are no symptoms because of this

The injury producing the fracture may also injure the deep divisions of the ulnar nerve and ulnar artery, presenting other problems The important effects of nerve pressure may require late treatment If the muscles supplied by the deep division of the ulnar nerve have not recovered within three months following the accident, the ununited unciform process should be excised, as the paralysis may be the result of pressure from this source

Fracture of the unciform process may also be a complication of dorsal dislocation of the unciform bone, but this presents a different problem (See Dislocation of Unciform Bone)

DISLOCATIONS

Dislocation of Wrist Joint

Dislocations between the radius and the carpus are extremely rare When they do occur they are apt to be complicated by fractures of carpal bones or of the inferior radial facet Uncomplicated dislocations are easily reduced, and splinting in a position of normal dorsiflexion should be carried out

for four weeks following which passive and active exercises should be carried on, aided by the comfort and help of physical therapy. The disability time to be expected is 8 to 10 weeks for clerical or light work and 12 to 14 weeks for the more laborious occupations.

Dislocation of Scaphoid Bone

Dislocations of the scaphoid are much less frequent than fractures The bone is usually displaced in a dorsal and radial direction, frequently with considerable rotation.[12, 27] Usually dislocation is complicated by fracture of the scaphoid or of some of the adjacent carpal bones

FIG. 786 First-degree dislocation of semilunar bone

If seen early after an accident, reduction may be effected by firm traction on the thumb and index fingers with manipulation and direct pressure over the dislocated bone. If this is unsuccessful, open reduction should be undertaken After reduction splinting should be provided with the wrist in normal dorsiflexion for four weeks. X-rays should be taken following this period, looking for evidence of lack of blood supply to the bone If such should appear, as evidenced by apparent increased density, prolonged fixation should be carried out until revascularization has occurred. If the condition should go on to aseptic necrosis without recovery, the bone should be excised This excision is done through a dorsal incision to the radial side of the common extensors of the fingers. (See Fig. 781.)

Dislocation of Semilunar Bone

This dislocation occurs more frequently than in any of the other carpal bones and it tends to follow a regular course of events (Fig 786). It may be complicated by fractures of adjacent bones Because of its shape, the bone practically always is dislocated anteriorly, when it may lie in one of three positions depending on the severity of injury:

1. The dorsal ligaments of the bone are ruptured or an avulsion fracture of the posterior horn may take place instead of rupture of the ligaments This allows the bone to escape anteriorly. With the anterior ligaments remaining intact, the distal concave facet comes to face the palmar aspect of the wrist and the upper convex surface faces the dorsum

2 The bone may be hinged by its anterior ligaments and rotate through 270° until its concave distal facet is facing dorsally and lying in contact with the anterior surface of the lower end of radius and pronator quadratus

3. The anterior as well as the dorsal ligaments are torn and the bone is displaced anteriorly and upward lying deep to the flexor tendons on the anterior surface of the lower third of the forearm anywhere above the level of the wrist joint.

In interpreting the x-ray evidence of dislocation of the semilunar bone, it must be realized that the concave distal surface of the semilunar does not contain the rounded head of the os magnum, and that the proximal convex surface is not lying in normal relationship with the distal radial facet. If these particular points are not observed, it is possible to confuse a dislocation of this bone with a midcarpal dislocation.

Treatment. If seen early after the accident, the first and second degrees of dislocations of this bone can usually be readily reduced. This is accomplished by firm traction[28] on the index and middle fingers by an assistant, with the wrist in extreme dorsi-

flexion. By manipulation and firm pressure[14] with the thumbs directly over the dislocated semilunar on the front of the wrist, the posterior horn can be made to enter the cavity between the os magnum and the articular facet of the radius. With the traction and pressure still applied the wrist is methods In the latter case, as the bone is completely detached from its blood supply, it should be removed through an anterior incision directly over it, as described below. The median and ulnar nerves and flexor tendons must be safeguarded during this procedure

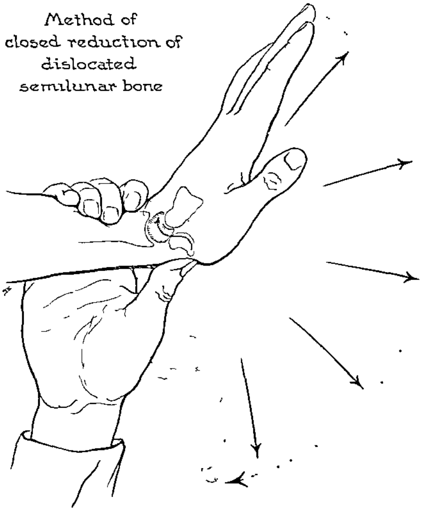


Fig. 787. Manipulative procedures for closed reduction of dislocation of semilunar bone.

brought into flexion, at which time the semilunar can be felt to return to its normal position

If the injury has not been recognized for several weeks, the difficulty of reduction increases with the lapse of time, if the semilunar has been dislocated into the third position, it cannot be reduced by closed

The first- and second-degree dislocations may be reduced in some cases as long as three weeks after the accident and occasionally at longer periods still. However, the difficulties at this stage are greatly increased because the space from which the semilunar was dislocated tends to be filled in by closing in of the adjacent bones and

by fibrous-tissue formation. If closed reduction fails, an attempt at open reduction should be tried in the early weeks following the accident.

Operation. Through an anterior incision, the median nerve and flexor tendons to the and cuneiform bones are manipulated gently to increase the size of this opening, following which it may be possible with leverage[20] and direct pressure to return the semilunar to its place (Fig. 788).

In late cases, if the bone is found to be

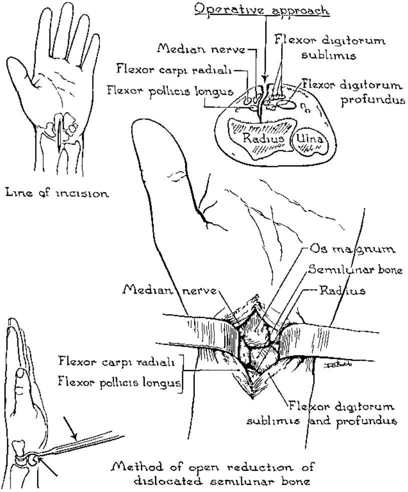


FIG. 788. Operative approach to anterior aspect of carpus and technic of open reduction of dislocation of semilunar bone

fingers are retracted to the ulnar side. The dislocated semilunar is found lying directly beneath these. Care is taken to avoid injury to the ligaments connecting the anterior horn to the lower end of radius. Excess fibrous tissue is removed from the space from which the bone was dislocated. With smooth elevators the os magnum, scaphoid, surrounded by fibrous adhesions with degeneration of its articular cartilage and the space from which the bone was dislocated is largely filled in, the semilunar bone should be removed.

Following reduction the wrist should be held in a straight position by splints for four weeks. At this time x-rays should be

made, looking for signs of increasing density or aseptic necrosis If such should appear, splinting should be prolonged until the bone has become revascularized If this is not done, the bone is apt to go through progressive stages of degeneration with collapse, finally giving the fully developed picture of Kienbock's disease For treatment of this condition see Fracture of Semilunar

Dislocation of Cuneiform Bone

No record of a dislocation of this bone has been found in the literature and in our group of cases there have been none

Dislocation of Pisiform Bone

Occasionally dislocation occurs when the pisiform is avulsed from the tendon of the flexor carpi ulnaris and lies in the adjacent tissue[19] It is difficult to reduce accurately to its original position and the closed methods of holding it are unsatisfactory It is better therefore as its function is more that of a sesamoid bone and as it takes no important part in the actual pressure bearing of bones of the wrist that it should be removed

This can be carried out through a short incision on the flexor surface of the wrist over the dislocated bone Care of the ulnar nerve and vessels should be observed during the procedure The prognosis is excellent and the disability time short even for heavy labor Active motion can be started as soon as the wound is healed

Dislocation of Midcarpal Joint

X rays following this injury are difficult to interpret unless this particular lesion is kept in mind The various carpal bones become superimposed on both anteroposterior and lateral x rays giving a confused appearance (Fig 789) In six cases[32] the injuries and displacements have been identical

The scaphoid is fractured across its waist The proximal fragment of the scaphoid with the semilunar bone remain undislocated and in contact with the articular facet of the lower end of radius The head of the os magnum is displaced and lies posterior to the concave facet of the semilunar and the

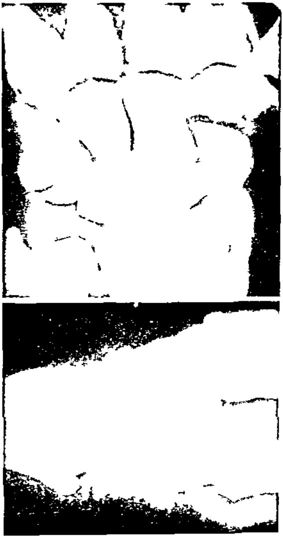


Fig 789 Midcarpal dislocation with fracture of scaphoid (*Top*) Anteroposterior view (*Bottom*) lateral view

distal fragment of the fractured scaphoid is displaced dorsally in line with the os magnum The trapezium trapezoid, and unciform retain their relationship to the distal fragment of the scaphoid and the os magnum and consequently are displaced dorsally with these bones The cuneiform lies at an angle between the medial side of

ciated with fracture of the unciform process. If there is no other associated lesion the bone dislocates onto the dorsal surface of the carpal region (Fig. 792). Unless the force causing the dislocation is very great, the bone usually remains in fairly close relationship to the adjacent bones. With more severe injuries it may be displaced considerably. In other cases, the unciform may be dislocated dorsally with relation to the adjacent carpal bones but may carry either the fourth or fifth or both metacarpals *dorsally with it. If seen early the dislocation* may be reduced by traction on the fourth and fifth fingers, by local pressure over the bone and manipulation. There may be considerable difficulty in preventing a moderate subluxation following reduction. The hand and forearm, from the metacarpophalangeal joints to the elbow, should be placed in a plaster cast with the wrist deflected downward and to the radial side, with the plaster carefully molded over the dorsum of the bone. If, in spite of this, there is a tendency to subluxation, a banjo splint with traction on the fourth and fifth fingers and with careful molding of plaster over the dorsum of the unciform will assist in maintaining the reduction. The plaster is maintained for four weeks, and followed by physical therapy and exercise If reduction has been complete, stiffness and swelling should subside sufficiently in eight weeks to allow return to clerical or typing work. Return to heavy work can be expected in from three to four months.

If these efforts fail or if the case is seen late after the accident, an open reduction should be undertaken.

Operation. The bone is reached through a dorsal incision over the ulnar side of the carpus (Fig. 781). The extensor tendons and dorsal branch of the ulnar nerve are protected. The space from which the bone came is cleared of fibrous tissue. The adjacent cuneiform, os magnum, and bases of the fourth and fifth metacarpals are gently manipulated to enlarge the space, when the body of the unciform may be forced down between the elevators into its normal position. The unciform process is always detached from the body and remains in its normal position in the palm of the hand Its fractured surface is cleared of fibrous tissue so that when the body of the bone is replaced either a bony or fibrous union may be expected. As the bone is roughly a truncated pyramid in shape, it tends to slip out of its cavity toward the dorsal aspect of the wrist. The dorsal ligaments *of the carpus should be stitched with silk* at various points to hold the bone in position and a plaster case, as described, applied

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34

Fractures and Dislocations of Metacarpals and Phalanges

JOHN PAUL NORTH, M.D.

Incidence. Fractures and dislocations of the metacarpals and phalanges are very frequently encountered in surgical practice. It is impossible to obtain any accurate estimate of their relative frequency from hospital case records or from x-ray files, since a great number of cases never apply at a hospital and many are treated by their physician without benefit of x-ray examination. A large number doubtless bear with a lame finger for several weeks without securing medical attention. The fact that this group is 12.5 per cent of all fractures and dislocations treated at the Presbyterian Hospital in New York—representing, as it does, only a fraction of the entire number—nevertheless gives some idea of the true incidence of these injuries.

A fracture of a metacarpal or phalanx is regarded as a trivial injury in comparison with a fracture of the femur. From the standpoint of immediate disability and length of time in bed, this may indeed be true. However, a poor functional end-result which involves a stiff finger may well be a greater economic handicap than a corresponding stiffness of, let us say, the hip. The economic importance of injuries to the bones of the hand can scarcely be overemphasized. Quite aside from the functional aspects, the cosmetic result warrants consideration. A crooked finger or an unsightly knob on the back of the hand is a deformity which cannot be concealed.

In view of the frequency of these injuries, as well as their importance in industry and the arts, it is surprising that so little attention is paid to them Textbooks devote little space to their consideration and the current surgical literature contains only a few general discussions of the subject and a scattering of papers advocating some particular splint or gadget for use in treatment. In the general considerations of the subject, the papers of McNealy and Lichtenstein and that of Owen are noteworthy

It is true that controversial subjects occupy most of the space in surgical literature and there is scant ground for argument concerning the diagnosis or management of fractures of the metacarpals and phalanges. This may account for the indifference of surgical authors toward the subject. Unfortunately, there is often a similar indifference on the part of surgeons in attendance upon these so-called minor injuries. The inevitable result follows that permanent disabilities of the hand appear, which might easily have been prevented had the cases received the early and detailed attention due to what are, in reality, injuries of the first magnitude.

SIGNIFICANT ANATOMIC CONSIDERATIONS

One of the conspicuous features of the hand is its palmar concavity which is exaggerated when the thumb and fingers are flexed in the position of functional grasp (Fig 793) The longitudinal axis of the *palmar saucer is formed by the curving* shafts of the metacarpal bones terminating at either end in prominent volar expansions or heads The transverse axis of the arch is produced by the ligaments joining the heads of the metacarpals and is accentuated by the thenar and hypothenar eminences These arches of the palm bear as important a relation to the function of the hand as do the plantar arches to the function of the foot and their preservation should be given particular attention whenever a palmar splint is employed If the splint material cannot be molded to conform with the normal contour of the hand suitable padding should be introduced in the palm

The diagnosis of fractures and disloca*tions of this region is facilitated by the ease* with which the bones may be palpated Some abnormalities are evident even on inspection—for example the dropped knuckle which is a significant sign of fracture of the metacarpal neck (Fig 94) Muscle attachments play some role in the *displacement of fractured fragments in the* hand as elsewhere and must be given consideration in determining the position in which the part is to be immobilized The attachments and function of the lumbricales are apt to be forgotten These muscles arising on the palmar aspect of the hand *and inserting into the proximal row of* phalanges aid flexion at the metacarpophalangeal joint but also by the virtue of their fusion with the extensor tendons they act as extensors at the terminal interphalangeal joint

FRACTURES OF THUMB METACARPAL

Bennett or Stave Fracture The most frequent type of fracture of the first metacarpal is one in which the line of fracture passes obliquely upward from the ulnar aspect of the metacarpal shaft toward or actually into the metacarpal trapezium articulation This the so called Bennett or

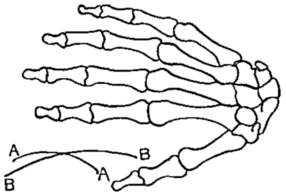


FIG 793 The palmar saucer Hand and carpus combined make a saucerlike concavity in both long axis (B) and short transverse axis (A) In using traction and splinting in the hand this should be kept in mind

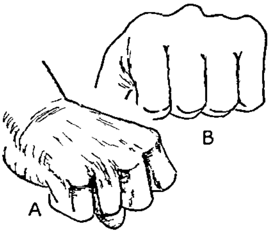
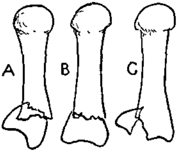


FIG 794 Dropped knuckle Semidiagrammatic view *from above* (A) *and* profile view (B) Correction of this deformity is basis of reduction procedure

stave fracture is caused by a blow directed against the tip of the extended thumb or against the end of the first phalanx or metacarpal with the thumb in flexion (Fig 795) The long distal fragment is displaced to the radial side and overrides the base

This fracture is accompanied by early swelling which obscures the deformity so that the injury is often incorrectly diagnosed as a sprained thumb. The outstanding symptom is pain on abduction of the thumb, noted especially when attempting to grasp an object or to oppose the thumb to the index finger. Comparison of the two hands may reveal that there is a loss of normal alignment at the site of injury or actual shortening of the thumb

This fracture may often be reduced quite easily by traction, but as soon as the traction is released the deformity usually recurs. Simple splinting, therefore, is not very efficient unless it can be combined with pressure over the displaced fragment, and the pressure required may be more than the soft tissues will tolerate. The classic dressing of a plaster spica, therefore, has a very limited field of usefulness, for some form of continuous traction is usually required. Moreover, the spica is usually applied with the thumb extended and hyperabducted in order to maintain reduction To this position Marble takes justifiable exception, preferring to dress the hand with the thumb flexed and set forward in opposition to the other fingers in the position of grasp (Fig 796) If a simple splint or a plaster cast suffices to secure reduction of fragments and also the physiologic position of the hand in a given case, either may be a satisfactory form of dressing and three weeks of immobilization are required. However, if either requirement must be sacrificed, some form of continuous traction must be applied to the thumb.



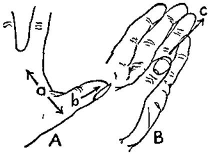


FIG. 795. (*Left*) Stave fracture of thumb The common type is represented by (A). Attempted abduction of distal fragment has opposition of thick muscle bellies which attach to it, and pure abduction has little effect on deformity unless rather firm and steady pressure is maintained to keep proximal end of distal fragment and lower fragment both in adduction (B) represents type which requires merely immobilization (C) represents the particularly difficult type In this type main shaft fragment tends constantly to partially dislocate from its carpal articulation.

FIG. 796 (*Right*) Grasp position for stave fracture of thumb The attempt to get reduction of deformity is usually made by abduction and traction (b) against force of thick muscle bellies which are thus put on the stretch (a) as in (A). With traction (c) made as illustrated in (B), by contrast, these muscle bellies are completely relaxed, and reduction is more easily obtained, more readily maintained, and in a position much more comfortable for patient.

Methods of Continuous Traction in Hand. The simplest method is a miniature Bucks extension with narrow longitudinal and circular strips of adhesive tape partly encircling the thumb or finger (Fig. 797). Care must be taken to avoid painful pressure of the tape upon the nail bed. It is not always possible to secure sufficient trac-

tion in this way and the adhesive may loosen without warning

Another method is to make traction via the fingernail by passing a mattress suture of wire silkworm gut, or silk through its tip (Fig 798) In the author s experience this is apt to be painful and insecure, although Key and Conwell and others recommend it highly

Japanese woven finger traps are used but they are dangerous and they have been known to produce gangrene

If skin or fingernail traction is not sufficient, the author prefers to resort to skeletal traction, employing a Kirschner wire or

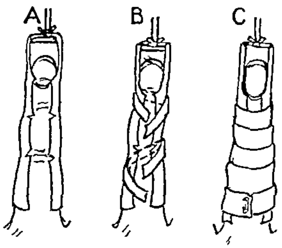


Fig 797 Adhesive finger traction (A) Application of lateral traction strips and a spreader Note that finger is not completely covered and that nicks in edges of strips allow accurate fitting (B) Application of stay strips Note that they do not completely encircle finger (C) Overall application of narrow Ace Elastoplast or other elastic bandage to minimize slipping

a needle drilled through the phalanx (Fig 799) In some instances when the wire is drilled from the side of the finger it will turn aside from the bone and pass only through soft tissues The author has in such cases drilled through the distal phalanx from a point on its dorsal aspect just above the root of the nail emerging on the volar aspect The problem of the bowing of the wire which occurs when using skeletal traction on large bones is not troublesome in the fingers for only a small traction force is needed Indeed, in using skeletal traction serious harm may result from overpull upon phalanges and their connecting ligaments

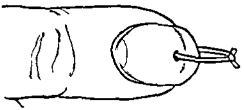


Fig 798 Fingernail traction Note that loop which may be flexible wire or *strong silk is passed through hole in* nail as far proximal as possible A kidney needle held in a pair of pliers is an excellent method of making this hole passing needle underneath distal edge *of nail gently forcing point as far prox*imal as possible and then coming up through nail

[The so called Japanese finger trap of woven wire or cord should not be used The risk of circulatory damage is real and the danger sufficient to interdict its use A thin leather glove finger glued to the digit with a ten cent piece in its tip to act as a spreader is much safer (Fig 800) Another *method of securing traction on the finger is* that advocated by Bohler through a wire loop passed through the pulp of the finger tip just distal to the tip of the terminal phalangeal bone and dorsally close to the fingernail (Fig 801) With the small amount of traction necessary in these hand cases this is said to be effective and is said to produce little if any discomfort Because of the density of the fibrous septa in the finger pulp it holds well I have seen it used and have used it but have never been able to feel that it is preferable to glove *finger or skeletal traction* It is however held to be preferable to either of these in the opinion of a number of men It is essential that the flexible wire loop be passed

deeply, just distal to the tip of the bony phalanx, and that a spreader be used to prevent approximation of the sides of the loop.—Ed.]

Having secured a traction cord to the finger, provision must be made for a point of fixation This is best obtained by applying a cuff of plaster of paris about the wrist directly to the wire frame or elastic bands may be introduced to take up any slack.

The application of skeletal traction to a Bennett's fracture is best indicated by Fig 804, which shows the use of skin traction upon the thumb Skeletal traction may be employed with the same apparatus. The flexed position of the thumb is preferable

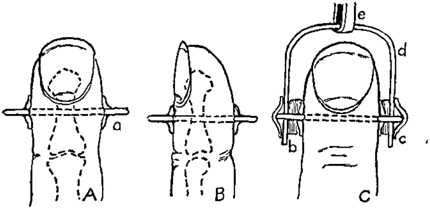


FIG 799. Skeletal finger traction. Kirschner wire through terminal phalanx—anteroposterior direction and lateral direction. (A) represents side-to-side insertion Small thin cotton collodion dressings are glued to pin and skin (a) (B) represents front-to-back method of insertion. (C) represents finished traction (b) is a small pad of felt to keep pin from sliding back and forth (d) is an aluminum or other flat strip serving as a traction yoke (c) is an adhesive-plaster strapping covering ends of pin and preventing yoke from slipping off. (e) is an elastic band for traction purposes

and incorporating therein a U-shaped loop of heavy wire such as that found in coathangers. This wire loop projects beyond the fingertips and may be bent to any desired angle so that traction may be made upon either extended or flexed fingers (Fig 802). If flexion is needed, slings between the side bars of the bent wire loop provide support for the finger and the traction cord is carried back to the wrist, thus drawing the finger in an arc upon the wire splint (Fig. 803). Böhler believes that a simple cuff is insecure, and advocates an unpadded plaster cast from elbow to knuckles, but if the plaster cuff is applied firmly but smoothly, using a strip of felt for padding over the styloid processes, this insecurity may be obviated. The traction cord may be anchored to a hyperextension provided it ensures a satisfactory maintenance of the reduction and fixation of the fragments.

FRACTURES OF METACARPALS OTHER THAN THUMB

These commonly result from blows on the knuckles during a fist fight or boxing match Fractures may occur at the neck or in the shaft of the metacarpal, and more than one bone may be involved There may not be any obvious deformity, the only signs being tenderness and swelling on the back of the hand Displacement when present usually takes the form of bowing with the apex on the palmar aspect. If this is not corrected, a troublesome disability ensues, due to the projection of the bone into the palm

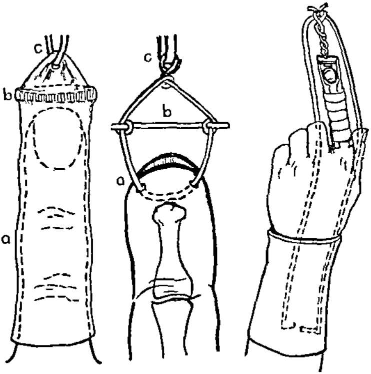


FIG 800 (*Left*) Glove-finger traction (a) represents finger of a thin leather glove which fits finger snugly and is glued on to whole length of finger with Sinclair's or other skin glue (b) represents a silver dime which is put into tip of glove finger before its application It acts as a spreader (c) is traction cord passed through a hole punched in tip of glove

FIG 801 (*Center*) Finger pulp traction Wire or heavy silk is passed through fingertip pulp as close to tip of bony phalanx as possible and emerging well laterally on either side of pulp A curved needle is used to carry wire or thread (a) A piece of Kirschner wire can be used as a spreader (b) A loop in wire or silk is used to carry elastic or other traction cord (c)

FIG 802 (*Right*) Plaster cuff and wire-loop traction Plaster cuff should be well molded, snug fitting, and with little or no padding Wire loop lies embedded in front of plaster Traction is that described in Fig 797, and its direction can be changed at will

where it interferes with the grasping of tools.

The characteristic deformity in neck fractures is a dropped knuckle, the head of the injured bone lying in front of a line drawn through the other metacarpal heads. Cases without displacement, or with slight bowing which is easily corrected, may be adequately treated by a dorsal splint of plaster molded to the hand. The angulation deformity may sometimes be corrected by bandaging the flexed fingers over a roller bandage grasped in the palm, but this dressing is unreliable, cumbersome, and immobilizes uninjured as well as fractured fingers. It is, therefore, not recommended.

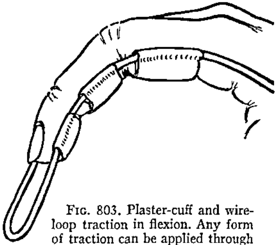


FIG. 803. Plaster-cuff and wire-loop traction in flexion. Any form of traction can be applied through end of wire loop. Slings provide adequate support in maintenance of any desired degree of flexion, and can be changed at will.

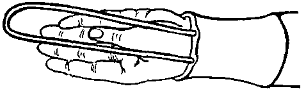


FIG. 804 Skeletal traction to Bennett's fracture. Wire loop is imbedded in radial aspect of plaster. Position of hand is that shown for Fig. 796.

[As a matter of fact this dressing, when used, should be limited to fractures of the shaft of the bone without overriding Here it conforms to the normal arch of the bone In the neck fractures, however, it tends to maintain or increase the forward angulation of the head fragment (Fig 805) The editor heartily agrees with the recommendation that it be not used

These neck fractures with forward angulation of the head fragment are frequently impacted and therefore difficult to reduce. The flexibility of the metacarpophalangeal joint makes the finger a poor source of leverage. Hyperextension at the joint tends frequently to increase the deformity (Fig 806). A method of reduction which can be employed is illustrated in Fig. 807, utilizing the clamp here shown, or any similar mechanism, to disimpact the fragments and to effect reduction.

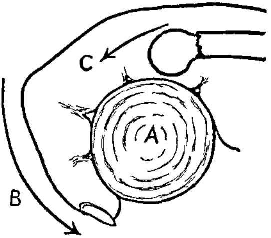


FIG 805. Effect of roller bandage on metacarpal-neck fracture. (A) represents roller bandage gripped in finger Last two phalanges are ordinarily bandaged around roller (B). Net result is a downward and forward traction on head (C).

The maintenance of reduction in these cases is often difficult The mechanism must employ dorsal fixation of the shaft fragment to the point of fracture with elimination of metacarpocarpal motion plus palmar support of the head and neck fragment to prevent re-angulation of the head into the

palm A mechanism for accomplishing this by a circular plaster gauntlet is illustrated (Fig 808) —Ed]

In the shaft fractures in which the obliquity of the fracture line presents difficulties due to overriding, a traction dressing should be employed in the manner described for fractures of the thumb metacarpal and with the finger corresponding to the injured metacarpal flexed upon the bent wire loop This will permit motion of the uninvolved

Open reduction and plating of these fractures has been done with excellent results from the standpoint of early active use of the hand It is a procedure requiring special plates and careful technic and should be reserved for the expert in bone surgery [See Chapter 22 for plating —Ed]

METACARPOPHALANGEAL DISLOCATIONS

The first metacarpophalangeal joint is

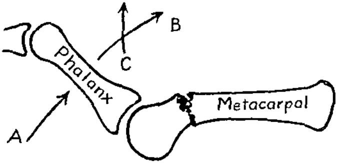


FIG 806 Effect of hyperextension on metacarpal neck fracture One might theoretically assume that hyperextension at metacarpophalangeal joint would correct forward angulation at neck Actually, straight hyperextension (A) as can be readily seen tends to depress head still farther Theoretically, a combination of hyperextension plus direct dorsal traction (B) and (C) should correct deformity Even if it did it would be extremely difficult to maintain these forces Actually, the procedure is not very effective

fingers during convalescence and thus avoid considerable stiffness Three weeks is usually a sufficient period for splinting although delayed union may be encountered necessitating longer immobilization

Fractures of the second and fifth metacarpals should have protection along the side in addition to that applied to the dorsum to correct any lateral deviation Bosworth has reported success in pinning a fractured fifth metacarpal to the fourth with two Kirschner wires (Fig 809) He advises that the wires be placed at an angle to each other rather than parallel and prefers that both pass through the distal fragment rather than one on either side of the fracture line as the latter allows rotation

dislocated more frequently than the other four combined The relative strength of ligamentous attachments at this joint is responsible for the frequency of injury as well as for the rather typical displacement The lateral ligaments are strong and are reinforced on the dorsal aspect by an expansion from the extensor tendon On the volar aspect, however, the glenoid ligament a fibrocartilaginous plate, is attached firmly to the phalanx but only weakly to the metacarpal head When the thumb is hyperextended, it is this weak anterior attachment which separates, allowing the phalanx to pass backward upon the radial aspect of the first metacarpal The displaced phalanx may assume an erect position, lying perpen

dicular to the metacarpal (the simple dislocation), or it may come to rest parallel with the axis of that bone (the so-called *complex* dislocation). When the latter occurs, the torn glenoid ligament may come to lie between the two bones, and offer an impediment to reduction, because traction in the axis of the thumb only wedges the torn ligament more firmly between the bones. In the complex dislocation, reduction can be secured only by first hyperextending the thumb so that it lies perpendicular to its normal axis and then, while traction is maintained in the direction of hyperextension, pushing the base distally until it clears the metacarpal head. The thumb may then be flexed into its normal position (Fig. 810). In a considerable proportion of cases, closed manipulation is unsuccessful, for, in addition to the obstacles cited, the tendons may encircle the neck of the projecting metacarpal bone like a collar

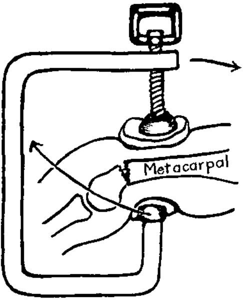


FIG. 807. Clamp reduction of metacarpal-neck fracture. This is an ordinary woodworker's U clamp. Felt pads are placed over distal portion of shaft anteriorly and posteriorly and clamp is screwed down tightly onto these felt pads. Screw handle of clamp is then suddenly forced in direction of arrow carrying butt of other end forward and upward under metacarpal head as illustrated by arrow. U shape of clamp makes it possible to apply it to any of the metacarpals.

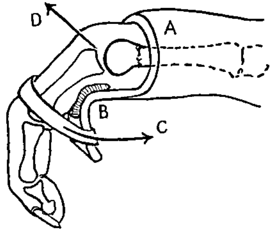
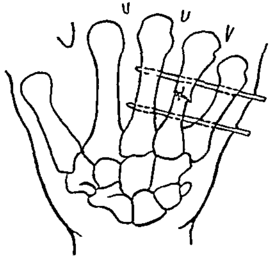


FIG. 808. Maintenance of reduction of metacarpal-neck fracture Following reduction a smooth-fitting unpadded plaster gauntlet (A) is applied to lower half of forearm and hand, excluding thumb This extends down to a point just proximal to fracture site It is accurately molded to shape of hand front and back so as to more or less grip metacarpal shaft. A molded plaster splint is then extended from lower end of this plaster distally underneath affected finger to a point about 1 5 or 2 cm. beyond metacarpophalangeal joint It is then bent at a right angle. While traction is maintained, proximal phalanx is then flexed over projecting edge of right angle in molded plaster splint with a felt pad (B) between finger and plaster. An elastic or other bandage (C) is used to hold proximal phalanx in this flexed position, leaving the two terminal phalanges free. Net result is traction plus a backward force exerted on head through first phalanx (D).

If closed reduction of the dislocation under anesthesia fails, resort must be had to operation, at which time the dislocated phalanx can be exposed and pried into position after the interposed glenoid ligament has been freed.

A splint or a bandage which will hold the thumb flexed upon the palm is *required for* five to seven days after reduction There after active motion should be encouraged as there is little likelihood of recurrence A seems to have been experienced in reducing *them by traction and pressure than with the* posterior variety

Dislocations at the other metacarpo phalangeal joints offer few obstacles to re



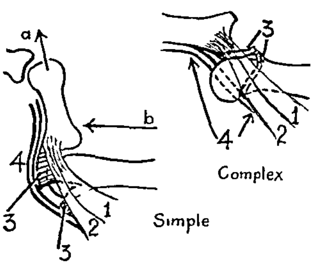


FIG 809 (*Left*) Kirschner wire pinning of metacarpal shaft fracture Fracture is reduced and the pieces of Kirschner wire pas ed as illustrated Ends can be left projecting covered by a small dressing or they can be cut off just beneath skin to be removed when union is comp'ete Under either circumstance fingers are free to move and patient can carry on considerable activity during healing of fracture

FIG 810 (*Center* and *Right*) Simple and complex dislocation of thumb

(*Center*) In simple dislocation position of bones is as illustrated with abductor poll cis (1) and flexor pollicis brevis (2) carried backward with phalanx on outer side Proximal portion of torn glenoid ligament is carried upward in front of metacarpal head (3) Flexor pollicis longus tendon (4) lies in front in simple dislocation Reduction must be accomplished by traction in direction of arrow (a) and simultaneous push against base of phalanx in direction of arrow (b) Straight distal traction may convert simple dislocation into complex dislocation

(*Right*) In complex dislocation of phalanx (often as result of ill advised straight traction) phalanx lies parallel with but dorsal to metacarpal It carries back with it torn glenoid ligament which becomes interpo ed between base of phalanx and head of metacarpal (3) Flexor pollicis longus tendon is carried backward on inner side (4) so that neck of metacarpal is bowstringed between it and abductor pollicis (1) and flexor pollicis brevis (2) Operative reduction is nearly always necessary Occasionally reduction can *be accomplished by causing phalanx to assume* position of simple dislocation and then by repeated attempts at clo ed reduction of simple dis location glenoid ligament can sometimes be milked from between the two bones

greater danger is that of prolonged stiffness and indeed some painful stiffness may be experienced for as long as two to three months after this injury under any condi tions Active motion is the best method of overcoming this disability

Anterior dislocations of the thumb have been described but are rare Less difficulty duction but if simple traction is not effec tual a maneuver such as that described for the thumb—traction in hyperextension fol lowed by direct pressure on the phalangeal base—should be attempted Subluxations are sometimes encountered and may become habitual they practically never cause enough difficulty to require operation

FRACTURES OF PROXIMAL PHALANGES

Fractures of the proximal row of phalanges have quite a characteristic tendency to angular deformity, concave on the dorsum, *due to the action of the intrinsic muscles* upon the proximal fragment. The practical application of this fact is the need for dressing these fractures with the involved finger or fingers in flexion, thus placing the distal fragment in the plane assumed by the proximal one.

Reduction consists largely in the correction of angulation since shortening is not much of a problem and very little traction is required upon the finger. There are several satisfactory methods of securing fixation with the finger in the flexed position That described by Jahss is one of the simplest:

The finger is flexed into the palm and anchored by two strips of adhesive tape crossed over the back of the finger and continued on about the hand. The author reports success with this method not only in fractures of the second to the fifth proximal phalanges but also in those of the thumb *Adhesive tape is apt to slip*, and, moreover, this dressing restricts movement of the uninjured fingers. A very satisfactory splint may be quickly fashioned from an ordinary large wire hairpin covered with adhesive and bent to the appropriate angle. This splint should extend at least from above the proximal flexion crease in the palm to the distal interphalangeal joint. *Others prefer to splint with molded plaster* of paris or aluminum or molded plastic strips. The splint, whatever its nature, is held in place by circular strips of adhesive reinforced by bandage. It is rarely that there is need for continuous traction on these fractures, but it may be employed if required. The difficulties encountered in correcting the angular deformity will dictate the method to be employed. Ordinarily the simpler methods are preferred, but not at the expense of permanent angulation, which may produce restriction in the action of the flexor tendons of the finger interfering with the making of a fist.

FRACTURES OF MIDDLE PHALANGES

The point of insertion of the superficial flexor tendon near the middle of the shaft is the factor determining the displacement in fractures in this segment of the finger. If the fracture line lies proximal to it, the tendon tends to draw the distal fragment forward. Obviously, an angulation of this *nature should be straightened out and the* finger placed on a straight splint. Fractures distal to the tendon insertion show a displacement which is the reverse of that just described, the proximal fragment being flexed. Accordingly, such cases should be treated with the finger flexed over a curved splint. The measures for securing immobilization have already been described in the *discussion of fractures of the proximal row* of phalanges Tongue depressors, wire hairpins, or molded strips of aluminum or plaster may serve as splints. They should extend sufficiently far up the hand to fix the metacarpophalangeal joint but should not interfere with normal use of the uninjured fingers.

The continued active use of the uninvolved *portions of the hand and fingers through the entire period of treatment* is exceedingly important in all phalangeal fractures. Any stiffening or disability of parts other than those fractured is attributable to treatment and not to the injury itself In applying dressings and in supervising the convalescence of the patient, provision should be made for active exercise. *Detailed instruction* should be given in the manner of carrying this out, and the patient must never be allowed to forget the necessity for exerting his own active efforts which are far more beneficial in contributing to recovery than any baking, massage, or passive exercises.

FRACTURES OF DISTAL PHALANGES

"Mushroom" Fractures Several types of fracture are encountered in the distal row of phalanges A common variety is the comminuted "mushroom" fracture resulting from a crush, as when the finger is caught in a press or other machinery or is pinched in a door Soft tissue damage is so conspicuous in these injuries that the fracture may be overlooked unless x ray pictures are taken Frequently there is a subungual hematoma or a compounding of the fracture The displacement of fragments is usually not extensive and may be overcome by simple molding For these comminuted fractures of the fingertip a wire hairpin provides an excellent splint although other materials serve well Whatever material may be chosen the splint should project slightly beyond the fingertip to protect it from the trauma of frequent painful contacts

[When fractures of the bulbous cancellous end of the terminal phalanx are compounded as well as comminuted and particularly if there is gross contamination the risk and extent of infection may be minimized by excision of the comminuted fragments as part of the wound toilet After such a procedure these wounds are much more apt to heal rapidly and without osteomyelitis and less apt to be habitually tender, yet the base of the phalanx which is retained gives sufficient rigidity to the fingertip to make it useful —Ed]

"Baseball" Fractures Another distinctive injury in this region is the so-called "baseball" fracture involving the dorsal facet of the distal interphalangeal articulation It is in reality a sprain fracture with a tearing off of a fragment of bone with the insertion of the extensor digitorum tendon Suturing of this tendino-osseous disruption is difficult, as the periosteum of the distal phalanx does not provide a sufficiently firm bite for the surgeon's needle The results of conservative therapy are satisfactory, provided early and uninterrupted immobilization is instituted and is maintained for a sufficiently long period The distal interphalangeal joint must be hyperextended to approximate the fragments and this hyperextended position must be maintained without interruption, even during the necessary changes of dressing, for from five to six weeks Plaster or aluminum may be used for splinting, or one of the several thimble shaped splints which are on the market may be used

[In the late cases, with the "dropped" fingertip resulting from inadequate conservative treatment, or following no treatment repair can be effected by a thin fascial suture threaded through the end of the tendon and passed through a side to side hole drilled through the terminal phalanx near its base The procedure is technically not easy is not too certain to be successful, and should be resorted to only if actual disability results from the dropped fingertip deformity —Ed]

Chip Fractures Chip fractures of portions of the articular surface of the phalanx may be encountered, especially if the traumatizing force has acted to produce a lateral deviation These fractures are often overlooked, in the absence of x ray, and erroneously considered to be simple sprains They should be suspected whenever there is a history of interphalangeal dislocation The occurrence of this type of articular fracture is not restricted to the terminal row of phalanges, but occurs at the other joints of the fingers as well Occasionally, a small fragment undergoes rotation or actually slips into the joint space so that it cannot be replaced by closed manipulation Such fragments require excision The usual case requires only simple splinting for about ten days If neglected, a painful stiff finger is to be anticipated [For further consideration of these sprain fractures see Chapter 41 —Ed]

Attention is called to the studies of Smith

and Rider on the healing of phalangeal fractures. They have shown that the fracture line remains visible by x-ray for as long as four to five months. Often the decreased density is even more evident after 30 days than it was immediately after the injury. Clinical union, however, is obtained in about one-quarter of this time, and treatment should be based upon clinical rather than x-ray findings to avoid the incapacity which would result from prolonged immobilization.

Fractures of this terminal row of phalanges do not, as a rule, exhibit any tendency to shortening, and hence continuous traction is not required. In cases in which an open wound makes it unfeasible to employ any form of external splint, fingernail traction may be resorted to, since traction on the skin obviously presents the same difficulties in care of the wound as does a splint.

INTERPHALANGEAL DISLOCATIONS

Dislocations of the fingers are very common and often are reduced by the patient himself without surgical aid. The luxation usually is posterior, although anterior or anterolateral dislocation is not unknown. Reduction is obtained by traction upon the displaced segment combined with appropriate pressure at the point of deformity. In dislocations at the terminal joint, reduction may be difficult, as there is little upon which to obtain a grasp Speed estimates that about 25 per cent of dislocations of the terminal phalanx are irreducible by closed manipulation and require open reduction. Before resorting to operation, it is well to introduce a Kirschner wire through the terminal phalanx and use this as a tractor. Some degree of disability may follow even successful reductions, but the serious crippling which is inevitable in old unreduced dislocations could be eliminated by operative reduction where closed maneuvers have failed.

COMPOUND FRACTURES AND DISLOCATIONS

Compound fractures or dislocations (see also Chapter 22) of these bones are extremely common and often comprise one feature of an extensive hand injury This is not the place for extensive discussion of wounds of the hand and only a few general principles which concern the bony injury itself can be emphasized here.

The fundamental problem is the avoidance of infection in addition to correction of deformity. If infection occurs, it becomes certain that the disability period will be protracted, that there probably will be considerable permanent impairment of function, and there may be actual loss of the part. Every effort must be exerted, therefore, to prevent the development of infection in the wound. This should be possible in most cases seen within six to eight hours of the injury. After the lapse of this amount of time the wound must be regarded as potentially infected

The measures by which sepsis may be prevented consist briefly in mechanical and surgical cleansing of the wound followed by reduction and adequate immobilization This is very simple in principle, but the practical details of its application are too often neglected, with disastrous results. During the first few hours after injury the invading bacteria are relatively few in numbers, and have not had opportunity to gain a foothold by deep penetration into the tissues. Painstaking but gentle mechanical cleansing with soap and water on cotton pledgets, the removal of foreign material, and the excision of all nonviable tissue will eliminate not only most of the bacteria present, but also the devitalized tissue which might serve as a medium for the propagation of the surving organisms.

Whether the wound may be closed after débridement, thus converting an open fracture into a closed one, is a matter calling for fine discernment on the part of the sur-

geon In general it is wise to take the con servative course of leaving the wound open If the period of contamination has already elapsed when the injury is first seen by the surgeon, it must be assumed that local sur gical intervention will result only in spread ing the infection Under such circumstances, the wound must always be left wide open without meddlesome interference and the resistance of the patient aided by supportive measures rather than by direct frontal attack

In cleansing a wound, we prefer to place our reliance on ordinary soap and water rather than on antiseptic solutions Those of the latter which are measurably active prob ably do more damage to normal ti sue than they do to bacteria The routine of soap and water cleansing should include, first, scrub bing the skin surrounding the wound, then cleaning the wound itself including its deep est crevices and pockets and finally a thor ough flushing with normal salt solution or sterile water This process should be carried out with meticulous thoroughness Too often it is done with a dab and a promise and is little more than a gesture

The next step is the careful excision or debridement of all tissue which has been deprived of its blood supply This should be done systematically, layer by layer In case of doubt concerning the sacrifice of a particular bit of soft tissue, the determining factor must be its viability rather than its functional importance By and large, bone fragments should be replaced rather than removed unless they are obviously nonessen tial Ample exposure of the depths of the wound must be obtained to ensure removal of all foreign material

When debridement has been accom plished, the question of skin closure must be faced If it is possible to do this healing is certainly accelerated, but there is also an invitation to infection Each case is a law unto itself in this regard, and there can be no general rules If the skin margins cannot be brought together without tension, resort may be had to one of several expedients Simplest of all is the use of relaxation inci sions parallel with the wound to permit closure, or the marginal skin may be con verted into a sliding skin flap which will allow the bone to be covered, leaving the site of the flap to be grafted later if neces sary A free graft of skin may sometimes be used to close the gap if other means fail Such grafts may serve a temporary protec tive purpose even if they do not survive but no form of closure should be attempted if there exists any reasonable doubt con cerning dangerous residual contamination of the wound

The dressing used on these open cases should make provision for the care of the wound Splints should be of a material which will not be damaged by exudates or wet dressings Skeletal traction on the fin gers is particularly useful Prophylactic tetanus and perfrigens antitoxin have their appropriate indications Sulfanilamide has proved its usefulness and there is some evi dence that the introduction of its crystals into the wound itself in addition to oral administration is of value in rapidly obtain ing a high local concentration of the drug [See Chapter 22 for discussion of chemo therapy —Ed]

[While some difference of opinion exists it is the consensus that severed tendons and nerves should be treated by primary suture, even if it seems possible that the wound may later become infected (See Chapter 42 for technic)

When treated in the contaminated stage it is always best to close the wound by any of the methods advised in the text This is practically obligatory when tendons are exposed

The cleaning and debridement of a hand wound are best done under a tourniquet While the skin is being thoroughly cleaned, the wound itself should be kept plugged with sterile gauze Benzine followed by alcohol, or ether may be used for the re moval of contaminating grease or oil Fol

lowing the completion of the wound toilet, the tourniquet should be released, and such additional hemostasis as is necessary should be *carried out. Meticulous hemostasis is* important in these cases.

A pressure dressing with even distribution of the pressure, to prevent distention of the tissues by edema and inflammatory exudate, is of great importance in minimizing the risk of tissue tension subsequent to operation which carries with it the risk of infection and tissue necrosis. Sea sponge, gauze fluff, or cotton, covered by an Ace elastic bandage, is excellent for this purpose. With such a pressure dressing badly contused or seemingly devitalized skin will act as a *primary skin graft.—Ed.]*

Amputation is to be avoided whenever possible as even the smallest unit of the hand may serve a useful function. It must be recognized, however, that at times the struggle to save an injured member may be carried on so long that useful function of the adjoining parts is lost by disuse and the stiffening incident to prolonged edema. The function of an entire hand may thus be jeopardized whereas *an early decision to* perform a limited amputation may reduce the length of disability, and also result in an increase in the usefulness of the remain*ing portion of the hand.*

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SECTION ELEVEN

FRACTURES AND DISLOCATIONS OF LOWER EXTREMITIES

35

Fractures of Upper End of Femur and Dislocations of Hip

LAWSON THORNTON, M.D.

This subject will include the different types of fractures encountered in injuries to the upper thigh, which, for the sake of convenience, are here listed: (1) Femoral neck, (2) intertrochanteric region, (3) shaft adjoining trochanter, (4) head of femur, (5) central dislocation of head with fracture of acetabulum, and (6) dislocation of hip joint.

FRACTURE OF FEMORAL NECK

Any discussion of fractures of the upper third of the femur centers upon the femoral neck as one of the sites most frequently injured as well as that having the highest percentage of nonunions (Fig. 811). Today a discussion of femoral-neck fracture entails a completely changed attitude from that of a few years ago, due to a new method of treatment. This changed attitude has resulted from the introduction of the Smith-Petersen nail, and a safe means of inserting it to hold the fragments accurately in a patient of any age without the necessity of external fixation.

The author considers this procedure the most outstanding contribution to fracture work in a number of years. Accurately applied, it assures the patient of a good walking hip in over 95 per cent of all cases, a percentage never reached heretofore, and for this reason he thinks it should be made available to every person having such a fracture.

[The percentage of good walking hips here cited as the result of pin fixation is somewhat higher than that generally claimed. The figures generally quoted in a national cross-section would be between 75 and 80 per cent. Not all of the unsatisfactory results are due to nonunion. Some of the cases which unite show degenerative changes in the next two or three years which result in stiff and painful unsatisfactory hips. The percentage of these cases is variously estimated at from 5 to 15 per cent of the total number. The median point of 10 per cent would probably represent the general finding.

It is interesting that this group of late degenerative changes after union is about the same whether closed reduction and plaster, closed reduction and lateral nailing, or open reduction and nailing is the method of treatment employed, and that in cases discharged from observation at the end of one year with union the percentage of these cases is low. This is due to the fact that the degenerative changes are slow and most often first give symptoms in the second or third year following injury, and are therefore missed. These changes are not necessarily preceded by the aseptic necrosis

described by Phemister The circulatory deficiency in these cases is usually not sufficient to produce massive death but is sufficient to induce the gradual degenerative change

The country wide average mortality rate after closed reduction and plaster is about 20 per cent The country wide mortality

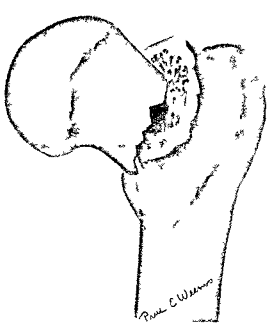

FIG 811 Fracture of neck of femur Backward rotation and upward rid ng of trochanter (Drawing made from x ray)

rate after pin fixation is not more than 10 per cent —Ed]

It is unnecessary to apply a plaster spica or any form of external splint Freedom of movement in bed is advisable from the beginning with daily use of a wheelchair allowable after the first postoperative day From an economic standpoint the saving is considerable Instead of weeks or months of hospitalization and specialized nursing as experienced in the past as a rule the number of days in hospital is no greater than that of a simple appendectomy and nursing is reduced to that of general care We have found that transportation of the patient for two or three hundred miles by ambulance can be undertaken safely making it possible to reach the nearest location which is staffed and equipped for handling such problems

The success of the method is attributable to the fine holding qual ties of the Smith Petersen nail and to the min mal surgery required to place the nail The s mpl city of the procedure and the rapidity with which it can be carried out are misleading to the inexperienced It is simple only when done properly and this calls for accurate knowledge of hip joint surgery

As employed in this country by Dr H H Wescott of Roanoke with personal modifications the details of the procedure as the author uses it are as follows

The patient is transferred to a wheeled stretcher from the ambulance and to avoid unnecessary pain is kept on this stretcher until the anesthetic is begun With a portable machine an x ray is taken without moving the patient from the stretcher Preparations are made for the operation the same day or night of the patient s arrival at hospital Examination of heart lungs and blood pressure is made and urinalysis is done If the heart is found fibrillating the operation is delayed for digitalization If drowsy from previous narcotics no pre operative drugs are given No elderly patient is given over 1/6 gr of pantopon

General anesthesia (cyclopropane) is begun and the patient is then transferred to a Hawley table which is provided with a tunnel for the reception of an x ray cassette beneath the patient For local preparation the entire extremity from toes to groin and up over the abdomen is painted with iodine and alcohol and the leg put through the opening of a laparotomy sheet A towel hook is fastened to the skin of the groin at the intersection of the femoral artery and Poupart s ligament as a landmark for later localization of the head of the femur The portable x ray unit is then rolled to the operating table on the side

opposite to the injured hip, and the tube is placed directly above the fracture. All operative work is done from the injured side, and all x-ray work is done from the opposite side.

The fracture is reduced by the combined movements of internal rotation, abduction, and a slight amount of traction, after which the extremity is placed on a leg board and held in the reduced position by an assistant. An anteroposterior x-ray picture is taken. While it is being developed, an incision is made over the lateral aspect of the trochanter on the side of the upper thigh and deepened through vastus lateralis to bone. The x-ray pictures are overexposed, are developed in warm, concentrated solutions, and are returned to the operating room in a few minutes' time. If the fracture has not been accurately reduced, a second manipulation is done and another x-ray picture made, and this procedure is repeated until a reduction is obtained which is as nearly perfect as possible.

[Many men take a lateral view at this point as well; the author of this chapter prefers it later, after the pin has been placed in the neck fragment.

Satisfactory reduction is rather largely held to call for a moderate coxa valga position of the head fragment on the neck fragment, the leg being carried out during the reduction into sufficient abduction to secure this position. Elimination of shearing strain and the establishment of a more direct weight-bearing thrust are the advantages claimed for such a position as compared with the re-establishment of normal anatomic position (Fig. 812). When the original fracture is impacted in this position, as is the case in roughly 10 per cent of cases (those in which the fracturing trauma has been a blow directly against the trochanter) the pinning is done without the necessity of reduction.

See the note at the end of this chapter for other methods of reduction used.—Ed.]

A Smith-Petersen nail is screwed on a White* handle. The author keeps on hand an assortment of Smith-Petersen nails of varying lengths but has found that the 3½-inch nail is required in the majority of cases. The nail must be long enough to bite deep into the head of the femur but not so long as to remain projecting laterally into the thigh muscles. Also, if too long it is liable to penetrate into the acetabulum.

Sinking the blunt end of the nail well into the lateral cortex prevents it from slipping outward with loss of fixation. The nail is

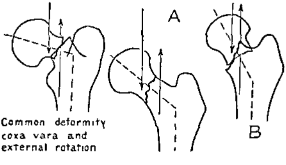

FIG. 812. Advantage of coxa valga position. (A) illustrates normal neck angle with presence of shearing strain; (B) shows how coxa valga position eliminates shear.

driven into the midlateral cortex of the femur a finger's width below the lowermost prominence of the greater trochanter (Fig. 813). The longitudinal direction is obtained by aiming toward the towel hook attached to the skin in the groin. The vertical direction is found by holding the handle, attached to the nail, parallel with the surface of the table. When the patella is rolled inward 20°, the neck of the femur should lie in a horizontal plane. An anteroposterior x-ray is made for a check, and, if desired, some may find that placing the gloved finger through the wound onto the front region of the neck will aid in guiding the nail.

At this stage the first lateral view of the fracture may be taken by flexing the hip and knee 90°. Care must be taken to main-

* Designed by Dr. Warren White, of Greenville, S. C.

tain internal rotation and wide abduction while flexing the hip and while replacing the extremity on the leg board in its extended position, in order not to disturb the apposition of the fragments

This is evidenced by a high pitched note *It is now just past the line of fracture* Again position is determined by x ray in both planes Should the nail not be in the center of the head it is partially extracted

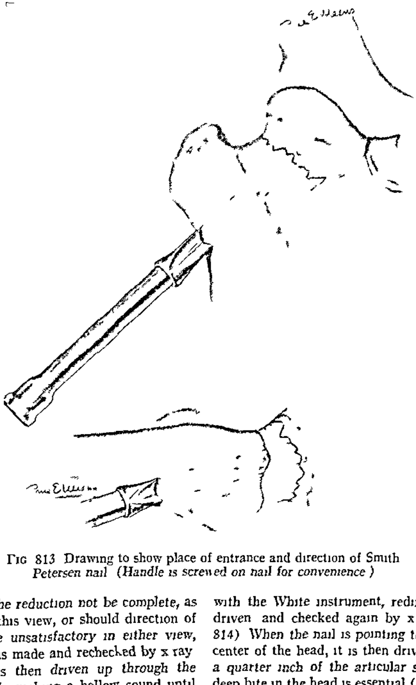

Fig 813 Drawing to show place of entrance and direction of Smith Petersen nail (*Handle is screwed on nail for convenience*)

Should the reduction not be complete, as shown by this view, or should direction of the nail be *unsatisfactory in either view*, correction is made and rechecked by x ray The nail is then *driven up through the* porous neck, making a hollow sound until it comes in contact with *the solid head* with the White instrument, redirected re driven and checked again by x ray (Fig 814) When *the nail* is pointing toward the center of the head, it is then driven within *a quarter inch of the articular surface* A deep bite in the head is essential (Fig 815) *Tight closure of the wound is important*

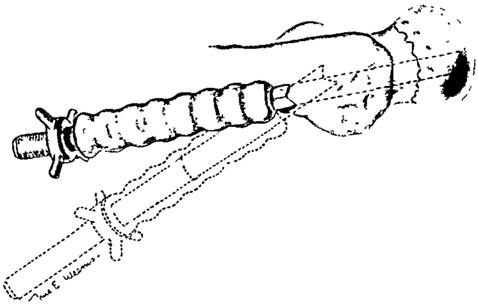

Fig. 814. Illustrating method of making correction if nail is not properly directed first time. Nail has been withdrawn with White extractor, redirected, and deeply driven in exact center of head of femur.

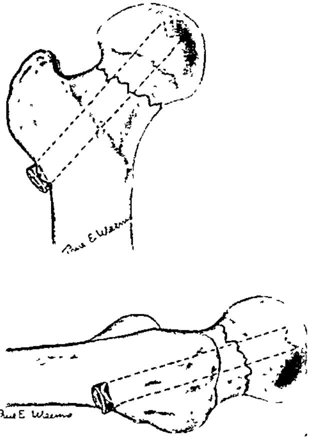

Fig. 815. Fracture of neck of femur. Illustrating reduction of fracture in both views and accurate placement of Smith-Petersen nail at completion of operation.

A small dressing is applied and the patient is put to bed in the sitting position if desired and without any form of external fixation. Early activity in bed and in a chair and early crutch ambulation is the indicated course. In the author's follow up care he suggests very light weight bearing on crutches in from 8 to 12 weeks and full

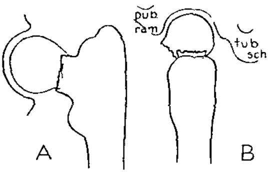

FIG 816 End-to-side position of femoral neck fracture as seen in anteroposterior and lateral views. (A) shows rounded appearance of head in anteroposterior view due to rotation of head fragment. (B) shows obvious lack of contact of fractured surfaces. Unless shaft is pulled outward head cannot rotate back to a neutral position since the two fragments are held tightly pressed together by tension of powerful muscles running from pelvis to lower fragment. In Leadbetter method of reduction, flexion of thigh relaxes these muscles.

weight bearing only when the x ray picture shows union (after 6 to 12 months or occasionally longer).

[There are a number of men who are convinced that open reduction and fixation secures results superior to those obtained by closed reduction and nailing. The open reduction is done through either a Smith Petersen incision or a Watson Jones incision. It is wise to drive the nail from the trochanter through the neck fragment and see that it appears in the center of the neck fragment before reducing the head and then to complete the driving secure in the knowledge that the nail is going directly through the center of the head. The fracture site is exposed by removing an anterior trap door from the capsule which is left unclosed at the end of the operation. The average point of insertion of the nail is $1\frac{1}{4}$ inches below the ridge representing the vastus lateralis attachment to the greater trochanter at exactly 45° with the shaft of the femur and parallel with the table, the patella looking inward 15 to 20°. In order to secure adequate coxa valga position some men remove a small wedge from the neck fragment's superior edge so that the head can be cocked up into valgus position.

In doing the pinning after a closed reduction some men drive a heavy wire from the trochanter through the reduced head and into the acetabulum so that there is no chance of the head kicking off when the nail is hammered through. The nail is passed over the wire or alongside the wire and the wire then withdrawn. Special cannulated nails are provided for driving over the wire.

Unfortunately closed reduction and plaster, the so-called conservative treatment—is often necessary because of lack of facilities for operative treatment, refusal by the patient for operation, or other circumstances. Closed reduction is accomplished by the method described above or by the Leadbetter method. In using the method described above, which is essentially the Whitman method, it must be remembered that occasionally an end-to-side position exists (Fig 816) as revealed by the lateral view. In that case before the internal rotation and abduction are carried out, the gentle downward traction should be accompanied by outward traction on the thigh to disengage the rotated head from the neck fragment, allowing the head to rotate into normal position. This allows the fractured surfaces to come into contact. The internal rotation and adequate abduction then result in proper reduction, which is checked by x ray.

Leadbetter Reduction. This is accom

plished by flexing the hip and knee to right angles, the pelvis being held down to the table by an assistant or by a band or sheet tied beneath the table. Moderate traction is then exerted in the long axis of the femur (in this instance upward), following which the leg is brought downward and outward into extension and abduction, with simultaneous internal rotation of the thigh. The traction maneuver can be carried out by pushing upward on the calf with one hand while supporting the foot with the other. Or, the calf can be placed on the shoulder of the operator, who faces the foot of the table alongside the patient and pulls downward on the lower part of the tibia, using the calf as the fulcrum to produce longitudinal traction on the flexed femur. Keeping his hold on the leg, he has only to "walk out from under" the calf as he carries the leg into extension, internal rotation, and abduction. Coxa valga is assured by carrying the extremity into 10° more abduction than is possible on the normal side. X-ray check is required to assure adequate reduction. In the absence of x-ray check, the securing of adequate internal rotation and impaction of the fragments is gauged by the Leadbetter sign, and the attaining of proper neck angle and femur length by the degree of abduction and by mensuration.

Leadbetter's sign consists in resting the heel on the side of the supposed reduction on the flat palm of the hand. If the leg and foot fall into external rotation either the rotation has not been corrected or the corrected fragments have not been impacted. If the rotation has been corrected and impacted, the foot remains upright.

Following reduction, the extremity is placed in plaster in the fully abducted and internally rotated position, with slight hyperextension at the hip, slight flexion at the knee, and with the foot in normal weight-bearing position in relation to the leg. This plaster can be either (1) the classic Whitman spica extending from the axillae down to include both anterior superior spines and the affected extremity down to the toes, leaving the sound leg and thigh free, or (2) a spica which extends only to the costal margins above, but includes both thighs, and the affected leg and foot down to the toes, leaving the sound knee, leg, and foot free. In the latter instance both

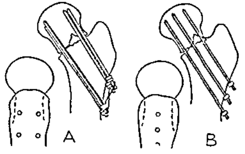

FIG. 817. The placing of Moore threaded pins (A), anchored by wiring together, and threaded pins as used by Carothers (B). The attempt is made to place Moore pins so that the two upper pins are against upper-neck cortex anteriorly and posteriorly, and the two lower ones similarly against lower-neck cortex. They are therefore placed by a hand chuck through a small drill hole in the cortex so that the contact with hard neck cortex can be felt as they are forced in. Only distal portions are threaded. Self-locking nuts prevent migration deeper into or through head, and outside ends are tightly wired together to prevent backing out of individual pins. Carothers pins are fully threaded, have lock nuts, and are placed parallel at as acute an angle as possible

thighs must be in full abduction if the pelvis is to be fixed. A broomstick fastened across the two thigh sections helps in shifting the patient.

The plaster must be left on for a minimum of eight weeks. It should then be bivalved and the fracture x-rayed without plaster, and the plaster replaced. Whether or not the plaster can be removed at that time depends on the information obtained by x-ray. The routine removal of plaster at eight weeks is to be deplored. The majority of intracapsular fractures require more than

that time in plaster If union at eight weeks is doubtful a new plaster is applied and the examination is repeated This can be continued for a total of 20 to 24 weeks, if the patient's condition warrants it

If at any time the conclusion is reached that union is not possible, one of the reconstructive procedures can be employed (See Chapter 15 for osteotomies and arthroplasties, and Chapter 22 for other procedures *for nonunion*)

Meticulous skin care, frequent turning of the patient, and as much physical activity as can be obtained from the patient are essential to freedom from decubiti and to a low mortality rate

It should be emphasized that bed rest, sandbags, and so-called judicious neglect today require great justification in any case *of fractured femoral neck*

Traction suspension in any of its forms is unsatisfactory in femoral neck fracture

Means of fixation other than the Smith Petersen nail are also used Moore pins (Fig 817) lag screws (*Henderson, Lorenzo* —Fig 818) and autogenous bone pegs (Fig 819) Multiple drilling from the trochanter through into the head at the time of the fixation has also been advocated (Boszan) to increase the changes of adequate vascularization The value of the *latter procedure is doubtful The bone peg* procedure requires external immobilization The consensus is that the Smith Petersen nail is equal to or superior to any of the others as a means of fixation —Ed]

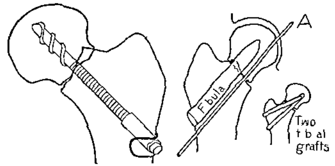

Fig 818 (*Left*) Lag screw fixation of femoral neck fracture Henderson lag screw illustrated Distal section is smooth and does not fit hole too snugly Effect of turning distal end is to draw head fragment tight against neck fragment at fracture line External curved metal plate washer prevents head from cutting through cortex

Fig 819 (*Right*) Autogenous bone-peg fixation using tibial or fibular bone peg Note coxa valga position and internal rotation of reduced fracture (A) represents a heavy stiff wire temporarily drilled through acetabulum to keep head from 'kicking' out of position as section of fibula is driven into it through a large drill hole It is removed when peg is in position If wire is not used it is necessary to keep thigh in abduction and internal rotation sufficient to maintain reduction during pegging *Coxa valga and oblique* direction of peg minimize shearing strain to which *latter is subjected*

TROCHANTERIC FRACTURES

The practice of treating these fractures with some form of traction is almost universal. Regardless of the method used, union practically always occurs, but union alone is not sufficient for a good result Traction must be applied to restore the normal obtuse angle made by the shaft on the trochanter and neck, otherwise there will be shortening (on account of the coxa vara produced) with limp and deformity (Fig. 820).

It is very important to make the definite distinction between an intertrochanteric fracture and a fracture of the closely adjoining femoral neck, as traction on the latter would seriously jeopardize union. Principles quite opposite are employed in the treatment of these two types of fractures.

External Fixation. Several methods of traction are available and all generally well known. For many years we have preferred and obtained good results with the Hoke plaster-traction apparatus. It provides a fixed type of continuous traction, complete immobilization of the fracture, and freedom from pain. The principle of this apparatus is that while traction is applied to the fractured extremity, counter-traction is being applied to the sole of the opposite foot. *The method in detail (Fig. 821)* is as follows:

A suit of stockinet is put on. Felt padding should line the back and sides of the body and the pelvic portion of the plaster. A double spica is applied, extending from the midabdomen to the toes of the unaffected leg and down the injured leg to a point above the fracture. The unaffected leg is held in a position parallel with the midline of the body to facilitate turning the patient from back to side and abdomen. The foot of the unaffected side is held in a normal weight-bearing position i.e., with the sole of the foot at a right angle to the leg. This foot should be well padded with sheet wadding. Felt has been found unsatisfactory for this purpose.

This entire procedure can be done without anesthesia by carefully transferring the patient to a Hawley table and by gentle handling of the leg. After the plaster has been applied a brief general anesthetic is given, or local anesthesia can be used if preferred. A Steinmann pin is inserted horizontally through the lower femur. Little hooks are screwed to each protruding end

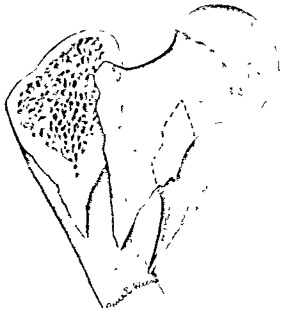

FIG. 820. Comminuted intertrochanteric fracture of femur. (Drawing from x-ray.)

of the pin and a very small size window-sash chain attached to each hook for traction. The lateral bars of the traction splint* are firmly attached to the plaster cast on the fractured leg by means of plaster bandages. A wooden cross-brace extends from the lower end of the splint—or, better still, from the attached heel support—to the cast on the opposite foot. Traction is exerted on the injured leg by winding the chain on the ratchet while counter-traction is exerted by the plaster cast on the sole of the foot of the unaffected extremity. For success it is necessary to have experience in applying a comfortable, well-fitting cast and a knowl-

*Made by the C. H. Martin Company, of Atlanta, Ga.

edge of the special nursing care required Outstanding advantages are accurate holding of the fracture and freedom from pain

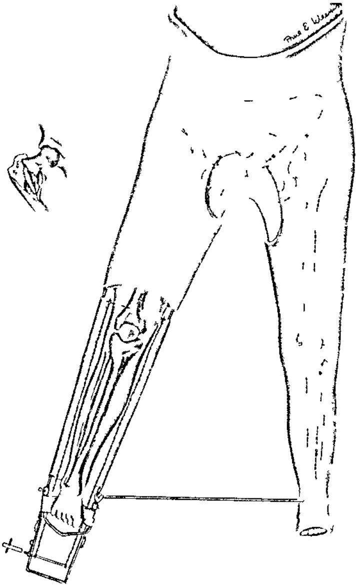

FIG 821 Hoke plaster traction apparatus as applied in treatment of intertrochanteric fracture of femur Traction is obtained by a ratchet attached to metal bars incorporated in cast Pull is made on femur through connection of ratchet to Steinmann pin (placed through bone above knee) with small chains

[Skeletal traction by a pin or wire through the lower femur or through the tibial tubercle skin traction through the thigh or leg or Russell traction are all effective See Chapter 22 —Ed]

Occasionally there is found a clean oblique break through the intertrochanteric region which can be reduced and desired result obtained by abduction of the leg and

holding it in this position with a double spica plaster cast.

Internal Fixation. A few years ago the author felt that the traction method could be replaced by one more direct and somewhat similar to that described for the femoral neck. Simplified after-care and comfort to the patient in the treatment of the femoral-neck fracture had far surpassed these points as applied to the intertrochanteric fracture. The author believed more progress could be made and began holding the fractures with internal fixation as described below. By means of a plate attached to the end of the Smith-Petersen nail, and secured to the upper shaft with screws and a Parham band, it was found that a good reduction is obtained and the postoperative care is similar to that carried out in fractures of the femoral neck (Fig. 822). He found no ill effects from the use of the additional metal.

[Another means of fixation in these cases is the use of the Blount-Moore gooseneck apparatus (Fig. 823). This, incidentally, is also adapted to the internal fixation of the osteotomies done for nonunions or other conditions.—Ed.]

In doing these open reductions it was often surprising to the author to see the wide separation of the fragments which exists and how, in certain types of these fractures, reduction is not brought about by traction. The split-off posterior fragment with adjoining femoral neck lies deep in the wound. The leg must then be rolled externally to close the gap before the Smith-Petersen nail is introduced. Sometimes a Parham band must be placed around the bones at the level of the lesser trochanter and drawn tightly to hold the gap closed before the fracture is nailed and plated (Figs. 824, 825, 826, 827, 828). Internal fixation requires the same precision and familiarity with hip surgery that is called for in the femoral-neck cases. With experience the operation is done almost as quickly as nailing a fractured neck of femur. A necessary instrument is the curved Parham band carrier with which the band is placed around the femoral shaft and plate.

The author suggests the use of this method of treatment to those familiar with

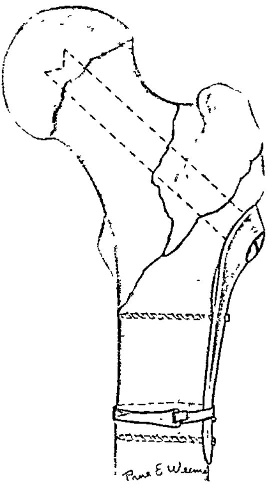

Fig. 822. Treatment of intertrochanteric fracture of femur by open reduction and internal fixation with Smith-Petersen nail, plate, screws, and Parham band. No cast or splint is necessary

hip-joint work and who have available the necessary special operating-room facilities for carrying out the procedure with accuracy and with little added risk to the patient. It is more surgery than that required for nailing the neck of the femur. However, with experience in doing this particular operation, the added surgery and time con-

sumed can be reduced to a minimum well within safe limits

SHAFT ADJOINING TROCHANTER

When the bone breaks in the manner shown in Fig 829, open reduction is necessary to overcome the displacement and give best chance for union

head epiphysis in children are treated by reduction and fixation just as in adult cases Union is, however certain and convalescence more rapid Old malunited displacements, or growth disturbances following corrected displacement should be treated by pin fixation and drilling across the epiphyseal plate If marked malunion is present it should be corrected operatively before pinning The object is to secure closure of the epiphyseal line

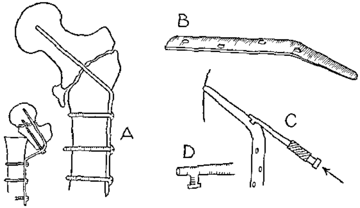

FIG 823 Blount Moore gooseneck for intertrochanteric fracture This is also used to maintain position without external fixation after osteotomies (A) Moore gooseneck plate holding intertrochanteric fracture No external immobilization is needed Inset shows high osteotomy held by Blount double angle plate (B) Moore plate and blade Note offset of holes in place and single hole in blade for driving purposes (C) Method of driving through chisel cut in cortex (D) Detail of end of driver which fits into hole in blade Plates can be bent at any angle or angles desired Driver works as extractor if gripped with pliers and pliers are tapped with a mallet

HEAD OF FEMUR

This type of fracture is rarely seen The use of the Smith Petersen nail would be indicated if enough of the head remains If the head is comminuted and the fragments displaced, a hip reconstruction operation (type dependent on details of fracture) would probably be the procedure of choice If healing takes place with a roughened and painful joint, one would consider the advisability of doing either an arthroplasty (provided enough of the head remained), using the Smith Petersen vitallium cup or a hip joint fusion operation

[Traumatic displacements of the femoral

Slipping epiphysis and the preslipping epiphysis are discussed in Chapter 18 — Ed]

CENTRAL DISLOCATION OF HEAD WITH FRACTURE OF ACETABULUM

There are cases in which by manipulation and traction it is possible to withdraw the head of the femur from its intrapelvic position Such a procedure should be done with extreme care and gentleness for fear

of injury to vessels, nerves, and organs within the pelvis, either through direct impingement or tearing by sharp acetabular fragments. Previous study of the x-rays

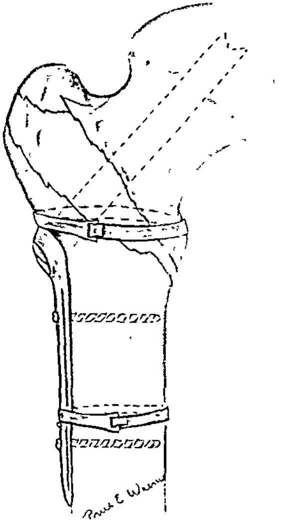

FIG. 824. Same method as Fig. 822 except type of fracture requires a circular Parham band to obtain reduction before nail-plate is applied.

would determine the advisability of such *manipulation.*

[Steady downward and outward traction under anesthesia, maintained while gradual abduction is carried out as in the Whitman method of hip reduction, will reduce some of them. Reduction can then be maintained by a Whitman spica, or by continuing the downward and outward traction, adding an outward force to a Russell traction, or to a skeletal traction by a pin through the lower femur or the tibial tubercle The Roger Anderson well-leg traction apparatus is a

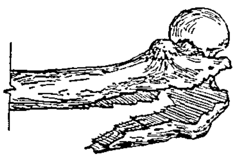

FIG. 825. Drawing from x-ray of long oblique fracture of upper shaft running into intertrochanteric region.

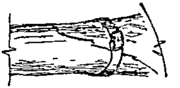

FIG 826. Parham band tightened

variant of Hoke traction. A pin may be put through the trochanter from before backward and used to produce the outward pull in conjunction with a pin through the lower femur or tibial tubercle for downward traction. A large screw may be inserted through the trochanter well into the neck of the femur and its protruding end used for downward and outward traction (Cubbins).

It should be kept in mind that many of these cases develop degenerative changes as the result of the damage done, and that in time one of the procedures described in detail in Chapter 15 may become necessary. —Ed.]

The author applies the Hoke plaster-traction apparatus (Fig. 830), with the

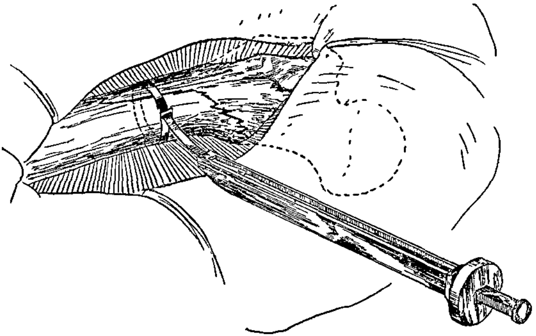

FIG 827 Fracture reduced and held with Parham band (Parham band tightener attached)

addition of a lateral pull by means of a Steinmann pin placed through the trochanter (See details of application of Hoke plaster traction apparatus, plus Steinmann pin put through trochanter with ratchet attached to cast for lateral pull) Downward and lateral traction are applied under frequent x ray visualization of the fracture until the head is reduced This must be maintained for from 8 to 12 weeks, following which the use of active exercises and gradual resumption of weight bearing on crutches is practiced Full weight bearing should be delayed from five to six months after injury

FIG 828 X ray 10 weeks after injury Solid union

The foregoing statements are general in character and are not presented with the idea that these different procedures can be considered as standardized for routine application Varying complications may be found that call for borderline decisions and modifications of technic, and therefore the course of treatment must be individually charted and carried out With a background of experience and bearing in mind the oft quoted 'personal equation" which makes each patient and his particular fracture a separate and distinct problem in its entirety, one must outline and follow to completion that method which seems best for the patient from the standpoint of safety and restoration of function

The following account was written by the Editor:

[DISLOCATION OF HIP

Dislocations of the hip today are relatively uncommon as compared with their former incidence, probably because much of the heavy work formerly done by man power is now done by machinery of various sorts. The so-called "dashboard" dislocation has appeared with the development of the low-slung driver's seat in automobiles. It is a direct backward dislocation caused by the impact of the knee against the dashboard of the car in a collision, and is frequently complicated by acetabular-rim fractures or head of the femur fracture.

Reduction of a traumatic hip dislocation, whether it be posterior (the usual form), or anterior (the unusual form) can be accomplished nearly always by traction without other manipulation if seen early. The manipulative methods described by Allis and by Bigelow are very rarely, if ever, needed. As a matter of fact, if the traction methods here described fail, open reduction is preferable if it can be done.

If the dislocation of the hip is the only injury, the patient is anesthetized and placed face downward on a table, with the hips flexed at 90° over the end of the table and the thighs and legs hanging directly down. The patient is held on the table and the knee on the affected side is flexed to 90°. Holding the lower leg just above the ankle in his hands to maintain the right-angle flexion, the operator seats himself astride the calf of the leg, and gradually allows his full weight to rest thereon. Five to 15 minutes of such steady traction will usually result in reduction in a fresh case.

Fig. 829. Open reduction was necessary in this type of fracture

If this fails, or in later cases, with the patient on his back and the hip and knee flexed to 90°, direct overhead traction via a pin through the lower femur and an overhead pulley combined with some outward

pull may be employed and if not successful immediately may be continued under moderately heavy sedation for 48 or 72 hours at the end of which time gentle direct manipulation may be successful If not open reduction is the indication Open reduction is described in Chapter 4 under congenital

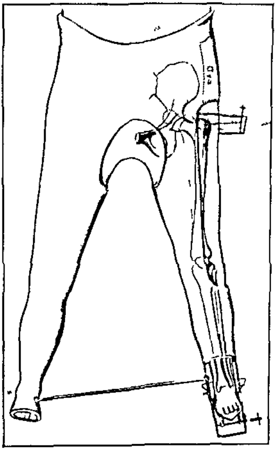

FIG 830 Use of Hoke traction plus lateral pull for central luxation of femoral head

dislocation, except that the capsular procedures are of course unnecessary There is no necessity for suturing the capsule after reduction and no necessity for immobilization unless associated acetabular rim fractures make redislocation a risk If this is the case suspension in mid rotation and abduction or a plaster spica may be necessary for from three to six weeks

Approximately 50 per cent of traumatic hip dislocations show later degenerative change in the hip joint These changes become apparent anywhere from one to five years after the injury with increasing stiffness and pain Whether or not the use of crutches or brace to delay the institution of direct weight bearing on the affected side for six months to a year following reduction diminishes the chances of degenerative change is uncertain Some men believe so and follow such a routine Others institute weight bearing with crutches within two or three weeks of injury and allow full weight bearing by eight weeks or so The presence of acetabular rim fractures may of course delay the institution of weight bearing

No matter what the course pursued the patient should be followed for a number of years both clinically and by x ray and on the first sign of pain or stiffness or of x ray change in the joint weight bearing should be refrained from for a prolonged period of months If this is done many of the cases will go on with good hips If however the changes continue to be progressive or if the signs and symptoms in the hip return on the resumption of weight bearing the procedures described in Chapter 15 for arthritis of the hip must be considered

The substitution of traction methods for manipulative methods of reduction is based on the lesser risk of sciatic nerve injury and on the lessening of trauma to already possibly compromised joint components

The presence of sciatic nerve symptoms in a hip dislocation calls for open reduction with inspection of the nerve Contusion of the nerve may be materially aided in recovery by ballooning the nerve out by injecting saline through a fine needle inserted within the sheath It tends to prevent scar tissue lesions within the nerve Laceration calls for repair Inspection of the nerve will sometimes be negative the lesion being in the roots or in the canal The prognosis in these latter cases is poor for return of function —Ed]

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36

Fractures of Shaft of Femur

ROBERT R IMPINK, M D

AND

WALTER ESTELL LEE M D

Fractures of the shaft of the femur occur most frequently as the result of direct violence suffered in industrial motor and military accidents and falls from heights The violence of the accident together with the trauma inherent in breaking this large bone result in at least a moderate degree of shock in every case Because of this factor these injuries represent problems in major surgery and their treatment therefore should be carried out under the direct supervision of an experienced surgeon

While the majority of femoral shaft fractures occur in youth or early adult life elderly patients are also frequent victims and these latter patients demand particular *attention Their declining physical status* must be recognized and supported but the fracture must not be too tranquilly relegated to a secondary position While investigating and fortifying the general condition the treatment of the fracture may and should be undertaken early It is often amazing to see the improvement in general well being which follows gentle reduction and fixation of the bone fragments Delay in attention to the local lesion encourages the development of complications In few other surgical problems is there so great a challenge to our ingenuity

[Definitive treatment for the fracture should be coincident with the treatment of the patient s general condition and should be considered part of the latter except in the moribund The authors make a point here which should be stressed It is unfortunate that the old popular slogan Treat the patient first and the fracture afterward has been carried down over the years to the present day It is fallacious teaching and in the aged and badly injured represents a great handicap to adequate treatment of either the patient or the fracture See Chapter 22 for further discussion Ed]

Femoral shaft fractures in children also require special consideration Because fractures in the first decade of life heal with *remarkable facility overcoming at times* even gross deformities there has developed a tendency toward the acceptance of imperfect reductions This practice is wrong The harm wrought in the physical and psychical developments of a child by the unnecessarily prolonged or permanent disability of a leg is difficult to overcome A poor reduction and persistent deformity requires compensatory alterations in the body mechanics during the most important period of bone growth The theory that such deformities are of no moment since they will be out grown should be discarded

[Shortening or angulation in a fracture

in childhood should be accepted only if the *period of spontaneous correction of deformity* is estimated to be short, and if the alternative is operative procedure or its equivalent. It is to be remembered that the ability to correct residual deformity steadily diminishes from infancy to the time of epiphyseal closure, and is absent after epiphyseal closure.—Ed.]

ANATOMY

Bone. The shaft of the femur is a relatively long and thick-walled cylinder. Its cortex is thickest in the middle third and tapers to thin shells at both extremities where the intricate trabecular systems of the trochanter, neck and head above, and the condyles below, oppose the various compressive and tensile stresses. Posteriorly, *the linea aspera extends as a rough longitudinal ridge* of bone in the middle third of the shaft and serves to buttress it and also as a line of attachment for muscles. When viewed from the lateral aspect the normal femur describes a slight curve with its convexity anteriorly, while in the anteroposterior plane there is a slight bow convex laterally. It is essential to restore these *curves after fracture in order to prevent* derangement of weight-bearing lines in the hip, knee, and ankle joints (Fig. 831).

Muscles. Anatomically, the muscles of the thigh are separated into anterior and posterior compartments by the medial and lateral intermuscular septa, which pass from the deep surface of the fascia lata to the inner and outer lips of the linea aspera. The lateral septum separates the short head of the biceps from the vastus lateralis, while the medial septum separates the vastus medialis from the adductor group.

Functionally the thigh muscles are divided into three groups: the flexors and extensors of the knee and the adductors of the thigh (Fig. 832).

The *flexor* group consists of the biceps femoris, semimembranosus, and semitendinosus, all of which take origin from the ischium. The biceps inserts into the head of *the fibula, while the semimembranosus* and semitendinosus insert into the medial aspect of the upper end of the tibia. These ham-

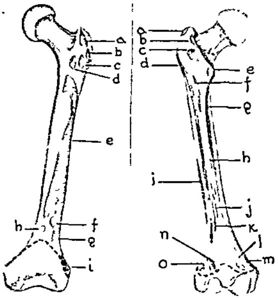


FIG. 831. (*Left*) Anterior aspect of femur. Dotted line below shows upper limit of quadriceps pouch. Muscle attachments shown are: (a) Gluteus minimus; (b), (c), and (d) attachments of vastus lateralis; (e) vastus intermedius; (f), (g), and (h) attachments of articularis genu or subcrureus; (i) adductor magnus.

(*Right*) Posterior aspect of femur. Dotted line below shows upper limit of joint compartment. Muscle attachments shown are: (a) Gluteus medius; (b) obturator and gemelli; (c) quadratus femoris; (d) vastus lateralis and gluteus maximus; (e) psoas iliacus, (f) pectineus and adductor brevis; (g) adductor longus; (h) short head of biceps; (i) vastus intermedius; (j) adductor magnus; (k) adductor longus, (l) inner head of gastrocnemius, (m) adductor magnus; (n) plantaris; (o) outer head of gastrocnemius.

string muscles flex the leg upon the thigh and extend the thigh upon the pelvis.

The extensor group, consisting of the rectus femoris, vastus medialis, vastus lateralis, and vastus intermedius, is called the

quadriceps femoris The rectus femoris arises from the ilium and the others of the group arise from the body of the femur from the trochanteric to the supracondylar regions The common tendon of insertion of this group is attached to the tibial tubercle The patella is present as a sesamoid bone in the tendon just proximal to its insertion inserted obliquely into the linea aspera along its entire length Their action as the name implies is to adduct the thigh on the pelvis

Blood Vessels The femoral artery and its accompanying vein lie on the medial aspect of the thigh Beginning just below the midpoint of the inguinal ligament these

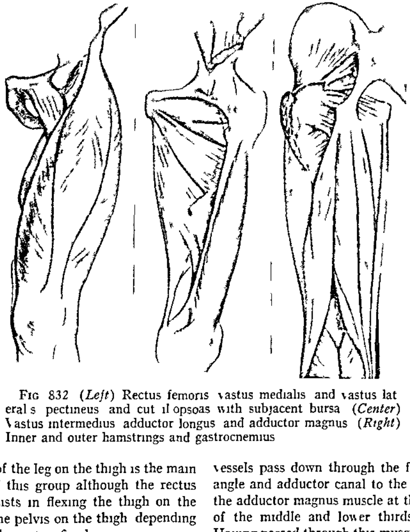


FIG 832 (*Left*) Rectus femoris vastus medialis and vastus lateralis pectineus and cut iliopsoas with subjacent bursa (*Center*) Vastus intermedius adductor longus and adductor magnus (*Right*) Inner and outer hamstrings and gastrocnemius

Extension of the leg on the thigh is the main function of this group although the rectus femoris assists in flexing the thigh on the pelvis or the pelvis on the thigh depending on which element is fixed

The medial femoral muscles known as the adductors comprise the gracilis pectineus adductor longus adductor brevis and adductor magnus These muscles arise from the anterior and upper surfaces of the rami of the pubis and ischium and are

vessels pass down through the femoral triangle and adductor canal to the opening in the adductor magnus muscle at the junction of the middle and lower thirds of thigh *Having passed through this muscular tunnel* the vessels enter the popliteal space and change their names to popliteal artery and vein As such they course medially and downward to the intercondyloid notch of the femur and thence vertically downward Injury to or rupture of the vessels occurs

occasionally in the popliteal fossa as the result of the characteristic posterior displacement of the distal fragment in supracondylar fractures.

Nerves. The important nerves of the thigh are the femoral and the sciatic. The femoral nerve accompanies the femoral vessels and is rarely injured by a shaft fracture. The sciatic nerve courses down the midline of the posterior aspect of the thigh, lying above at a point midway between the ischial tuberosity and the greater trochanter. This nerve is sometimes damaged by a fracture of the shaft since it lies directly against the bone beneath the biceps femoris muscle. When injury of the nerve is suspected immediate operative exploration is indicated.

DISPLACEMENT

The malposition of the fragments of a fractured femur is determined by the actions and counteractions of the three groups of powerful thigh muscles above described. To a much less degree gravity influences the displacement of fragments, particularly in the sagging associated with a midshaft fracture as the patient lies supine. Furthermore, the displacement is typical and fairly constant at various levels of the thigh, thus proving that muscle action, and not the fracturing force, is the determining factor. Shortening with overriding of the bone ends, together with external rotation of the upper fragment due to the action of the muscles attached to the greater trochanter, is the characteristic pattern of deformity. There

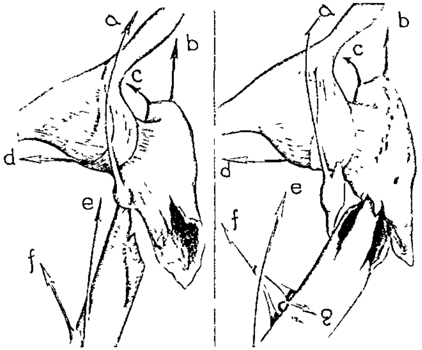


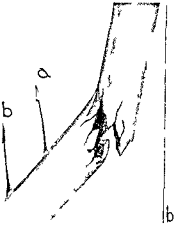
Fig. 833. (*Left*) Forces causing displacement in upper third fractures with lesser trochanter intact. (a) is flexion force; (b) and (c) are abduction forces; and (d) is external rotator force, all acting on upper fragment. (e) and (f), acting on lower fragment, constitute an adduction and shortening force.

Fig. 834. (*Right*) Forces causing displacement in upper third fractures with lesser trochanter avulsed. Flexion force (a) is now ineffective, and in its absence some external rotation force (g) is active on lower fragment.

is generally some degree of external rotation of the lower fragment when the patient is on his back since the foot and leg tend to be rotated outward by gravity (Figs 833 834 835, 836 837)

Fractures in Upper Third of Shaft The displacement in fractures in the upper third of the shaft is remarkably constant The short upper fragment is externally rotated abducted and flexed The short rotators chiefly the obturators internus and externus the gemelli superior and inferior and the pyriformis all attached to the greater trochanter cause the external rotation Abduction results from the action of the gluteus medius and to a lesser extent of the gluteus minimus The strong iliopsoas tendon attached to the lesser trochanter flexes the upper fragment The lower fragment is pulled upward and inward behind the short upper fragment by the muscle groups which bridge the fracture line The hamstrings quadriceps femoris and adductors bring about this shortening and medial angulation (Fig 838)

It is essential to recognize the mechanics of the deformity in subtrochanteric and upper third shaft fractures because of its bearing on reduction The short upper fragment cannot be controlled or manipulated except by means of skeletal fixation Therefore alignment can be attained only by bringing the long lower fragment to meet the short upper fragment When dealing with the typical deformity this requires abduction and external rotation of the lower fragment



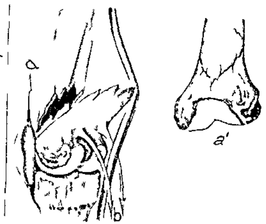


FIG 835 (*Left*) Anterior view Forces causing displacement in middle third fractures
FIG 836 (*Center*) Lateral view Forces causing displacement in lower middle third fractures The marked tendency to overriding through forces of long thigh muscles (a c d and e) with backward pull on lower fragment from action of latter three and absence of marked backward tilting by gastrocnemius force (b) on lower fragment because of stabilizing effect of upper forces is clear
FIG 837 (*Right*) Lateral view Forces causing displacement in supracondylar fractures Inset shows line of fracture in anteroposterior view Note threat to popliteal vessels

Fractures in Middle Third of Shaft In fractures of the midshaft region (Fig 839) the displacement of the fragments is not constantly predictable Shortening is a common finding due to contraction of the muscles which cross the fracture line Anterior displacement of the upper fragment resulting from the action of the iliopsoas and posterior displacement of the lower fragment due to the action of the gastrocnemius and popliteus muscles are usually present The nature of lateral angulation if any, varies with the level of the fracture

i.e., with the length of bone affected by the adductor muscles. In fractures of the upper portion of the middle third the upper fragment will be abducted, while in those of the lower middle third it will be adducted. In certain cases of fracture of the lower portion of the middle third the lower fragment is drawn upward and its proximal end displaced laterally as the result of contraction of the strong adductor magnus tendon attached to the adductor tubercle. Thus, with abduction of the upper fragment an angulation, convex laterally, is produced. Reduction of this type of deformity can be accomplished only by further adducting the lower fragment, thereby relaxing the muscle, until the bone ends are in contact, and only then correcting the adduction deformity.

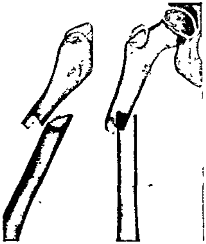


FIG. 838. (*Left*) Lateral view. (*Right*) Anteroposterior view. X-ray of fracture of lower upper third in a child. Flexion, abduction, and external rotation of upper fragment with overriding.

FIG. 839. (*Left*) Lateral view. (*Right*) Anteroposterior view. X-ray of fracture of middle third. Overriding, adduction, and rotation of lower fragment.

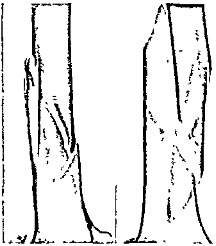


FIG. 840. (*Left*) Lateral view. (*Right*) Anteroposterior view. X-ray of fracture junction of lower and middle thirds. Some overriding and some adduction of lower fragment.

Fractures in Lower Third of Shaft. In fractures in the lower third of the shaft (Fig. 840) and of the supracondylar region there is almost invariably some degree of posterior displacement of the distal fragment. The attachments of the tendons of origin of the gastrocnemius muscles in the supracondylar notches cause this displacement by rocking the femoral condyles forward and by pulling the attached shaft portion backward as the muscle contracts. The popliteal vessels and nerves may be contused and are occasionally severed by the sharp edge of the distal fragment. Overriding of the fragments is usually increased by contraction of the thigh muscles as a group. A lateral displacement of fragments at this level is not marked nor is it constant in any one direction.

SPECIAL DIAGNOSTIC SIGNS

A recapitulation of the common diagnostic signs of fracture of the shaft of the femur is without the province of this volume. However, there are certain signs, encountered rarely, but with special significance from a therapeutic point of view, which deserve consideration.

1. Ecchymosis. In many femoral-shaft fractures ecchymosis is absent because the hemorrhage, even if massive, is prevented

from reaching the subcutaneous level by intact muscular and fascial layers of the thigh After from five to ten days irregular patches of ecchymosis may appear as the blood seeps to the surface along muscular planes This is the normal picture

Rarely one will note the appearance of extensive ecchymosis within two or three hours after a fracture This phenomenon indicates the laceration or tearing of muscles and subcutaneous tissues by a sharp fragment whose course stopped just short of penetrating the skin In this type of injury often a large volume of blood is liberated into the tissue spaces and thus the fracture becomes a more complicated problem

Shock of varying severity depending largely upon the volume of blood loss is a common sequel Distension of the thigh increases until the pressure in the hematoma is sufficiently great to prevent further bleeding As distension increases pain becomes more severe and thereby the tendency for the development of shock is augmented Finally the blood under pressure in the hematoma tends to infiltrate the torn muscle and fascial planes over a large area The immediate inflammatory reaction and later organization of such a lesion are detrimental to early union of the fracture and cause important damage to soft tissues In many cases bony union is long delayed in others disability prolonged due to muscle injury

When such an extensive early ecchymosis is discovered immediate operative exploration of the fracture site is indicated The hematoma should be evacuated traumatized muscle excised hemostasis assured and the fracture reduced and fixed by a metal plate and screws This is the only certain way of avoiding the disabling secondary effects of this type of soft part lesion

[The effect on the shock picture of the absorption of this really tremendous mass of hemorrhage and autolyzed products of tissue death is often not fully appreciated A liter and a half or more of fluid frequently is accumulated in a fractured thigh The bearing of this fact (1) on the treatment of thigh fractures with severe soft part damage (2) on compound fractures and (3) on the timing of any operative procedures is discussed in Chapter 22 Ed]

2 Excessive Swelling Occasionally one encounters an extraordinarily massive and tense swelling of the thigh without evidence of ecchymosis following femoral shaft fractures Pain at the fracture site is much more intense than in a simple fracture and shock is pronounced The swelling and tenseness increase progressively

The pathology in these cases consists of profuse hemorrhage which is confined within the fascial envelope of the thigh The hemorrhage may arise from a laceration of the femoral artery or from the severance of a deep communicating vessel The latter event may impair the circulation of the leg seriously by causing sufficient pressure within the deep muscle fascia compartment to reduce the blood flow in the large vessels passing through these spaces to a dangerously low level Muscle tissue is damaged by the infiltration of blood under pressure and also by the ischemia caused by the pressure of the hematoma proper on the muscle capillaries

3 Circulatory Disturbances These may be manifested by a change in temperature with beginning discoloration of the part below the site of fracture and the early recognition of such an existing condition is extremely important Such changes are most likely to occur in fractures of the supracondylar level and in all such cases careful examination should be made for the presence of a dorsalis pedis and a posterior tibial pulsation The presence diminution or absence of pulsation should always be recorded in cases where plaster encasement is to be employed Among the extremity injuries encountered in modern warfare this is of prime importance and proper manage

ment of such a condition may avoid the loss of a limb.

TREATMENT OF FRACTURES OF SHAFT OF FEMUR IN INFANCY AND CHILDHOOD

The presenting picture of shaft fractures in this age group is practically the same, with shock, deformity, and pathology, as is encountered in fractures of corresponding levels in the adult. In essence the treatment is similar, yet varied slightly because of lack of development in size and strength of the leg muscles. For this reason this group is more amenable to manipulative reduction and plaster-cast fixation than is the adult group. Here also the greenstick type of fracture may be encountered. Any type of treatment applicable to the adult may also be employed in the treatment of fractures of the femoral shaft in infants and children when so indicated.

When traction is the method of choice for treatment, the Bryant's vertical extension apparatus (Fig 841) is the one most commonly used in children up to the age of six. [The feasibility of Bryant's traction is dictated for practical purposes by the weight of the child. Many men therefore set an upper limit of 50 pounds as the maximum beyond which Bryant's traction is not feasible, rather than an age limit. This might exclude a great many children six years of age.—Ed.] This procedure requires the application of adhesive strips for traction extending from the upper thirds of both thighs, inner and outer surfaces, to points just above the malleoli. The distal ends of the strips are attached to spreaders as described in other adhesive skin traction set-ups. From the spreaders ropes lead vertically upward over pulleys suspended from an overhead frame. Weights attached to the rope ends must be just heavy enough to

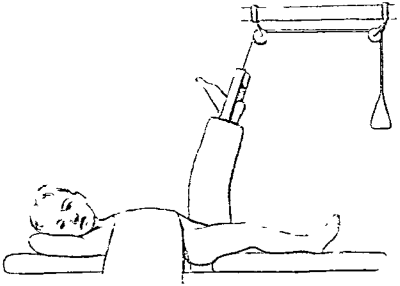


FIG. 841. Bryant's traction A snug pressure dressing is applied to extremity over adhesive straps The author prefers suspension of both legs as providing better control. The restraining sheet is shown The error in suspension commonly committed is also shown—the weight used should be sufficient to lift the buttock just clear of the mattress or frame so that the child's body weight provides adequate counter-traction and so that nursing is facilitated.

lift the buttocks and lower portion of the back from the bed If the child tends to be restless it is advisable to fix the body to the mattress by a restraining sheet or better still by a specially designed restrainer such as Conwell has devised Occasionally further restraint in the nature of an adhesive swathe which binds the thighs together may be indicated

It is surprising to note the rapidity with which children become accustomed to this

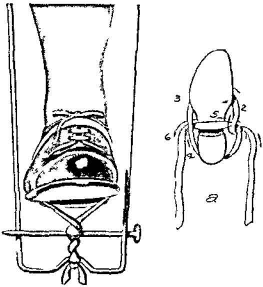


Fig 842 Emergency fixed Spanish windlass traction to bottom of a Keller Blake or Thomas splint Inset (a) shows formation of hitch used

position Traction is maintained for from six to eight weeks or until union is firm After an additional week in bed without support the patient may be allowed to walk with crutches bearing no weight on the affected leg Lateral splints or a single hip spica and casing for the entire limb should be used to support the affected thigh for a period of four weeks At the end of this time the splints are removed and weight bearing is permitted with the aid of crutches if the child is old enough for crutches Walking without crutches is usually safe 15 weeks after the occurrence of the fracture For children older than six years the Russell extension principle may be used satisfactorily (see Fig 844) With this type of treatment traction is maintained for from six to eight weeks and followed by one week in bed without traction From this point the progress is similar to that noted above for cases treated by the Bryant s extension method

It is almost never necessary to utilize skeletal traction in children except in the presence of a compound wound or other skin lesions which preclude the application of adhesive traction

[In children old enough to have acquired adequate control of bladder and bowel so that constant soiling need not be feared manual reduction followed by plaster spica immobilization or Hoke s well leg adhesive traction in plaster are both widely and successfully used These shorten hospital stay and simplify the care of the patient when these factors are matters of particular consideration The plaster immobilization and *Hoke s traction are described later in this* chapter Hoke s traction is also described in Chapter 35

Le Mesurier s method of traction is another valuable method applicable to children This is described in Chapter *22* in the discussion of traction suspension —Ed]

TREATMENT OF FRACTURES OF SHAFT OF FEMUR IN ADULT

The treatment of femoral shaft fractures in the adult may be divided into two distinct phases one of which deals with the emergency treatment the other with the reduction and permanent fixation It is impossible and unnecessary to decide which phase is more important but the value of proper emergency treatment must be stressed

Emergency Treatment

The immediate care of a patient with a femoral shaft fracture has a bearing not only on the final alignment of the fragments

and the ultimate healing of the fracture, but also in many cases on the very life of the patient. Accentuation of the shock, which is usually severe following this injury, by misdirected or total absence of proper first aid has been the cause of death in many of these cases. The three factors mainly responsible for the production of shock are (1) pain, (2) injury to the soft tissues caused by undue motion of the fragments, and (3) hemorrhage. Therefore, the pain must be relieved at once by morphine in adequate dosage, and the thigh must be immobilized as soon as possible.

Immobilization is best affected by means of fixed traction in a Thomas (Fig. 842) or Keller-Blake splint. Pain caused by motion of the fragments is thus prevented and in addition the onset of muscle spasm and infiltration (which occur early and account for overriding of fragments and shortening of the limb) may, by this means, be avoided or counteracted. When traction has been applied via an emergency splint within a few minutes after the fracture, the x-ray frequently reveals the fragments in practically anatomic alignment. Occasionally one is embarrassed by the loss of this excellent position in the transition from the temporary to the permanent traction apparatus. [For a full discussion of the emergency treatment in fracture cases, see Chapter 22.—Ed.]

If a Thomas splint is not available, boards, broomsticks, ski poles, forked branches of trees, or any other sufficiently long stick may be ingeniously utilized with the aid of a few triangular bandages to apply traction to a fractured leg. Traction is the more effective method of emergency splinting. If the materials for applying traction are not available, simple splinting may be carried out with boards lashed to the lateral and medial aspects of the leg while manual traction is employed.

When a patient who has received proper first-aid treatment arrives at a hospital, it is a primary requisite to continue adequate shock treatment. Rest, warmth, sedation, transfusions of blood or plasma and other appropriate medication are the well-known measures for combating shock. An x-ray examination of the fracture adds a certain amount of trauma, but this is very slight if the procedure is performed carefully and with a minimum of movement of the affected leg. X-rays should be taken promptly, unless the patient be in extreme shock, because the information gained from them may be of great importance for subsequent treatment.

The removal of the emergency splint and the application of permanent traction, or of some other form of permanent fixation, must be timed carefully in a shocked patient. This requires a nicety of judgment which comes only with experience. If there is doubt concerning the ability of the patient to withstand even the most gentle manipulation, it is best to continue shock treatment only and defer treatment of the fracture. On the other hand, if the shock treatment is carried out painstakingly and the patient's condition watched carefully, improvement is usually noted within one or two hours. As soon as definite signs of recovery are noted treatment of the fracture should be undertaken. It may be necessary to carry out the treatment in several stages with interruptions to allow the circulatory system to resume its recovery. It is important to emphasize that the fracture treatment must not be delayed simply because of the existence of a mild degree of shock. Fixation of the fragments is one of the best methods of combating shock.

[For detailed discussion of shock therapy see Chapter 22. The authors here make a point which is of great importance. A great deal of unnecessary and actually harmful delay is occasioned by the widespread idea that adequate fracture treatment must be delayed until the patient has fully rallied from his shock. This is not so. Intelligent handling makes it possible to treat adequately and concomitantly both shock and

fracture in all except the practically moribund cases —Ed]

Permanent Treatment

The four ways in which reduction and fixation of fractures of the femoral shaft may be accomplished are as follows

1 Continuous traction by means of one of the various methods of traction suspension

2 Closed reduction and immediate immobilization in plaster

3 Closed reduction by means of levering and manipulating with pins or wires inserted above and below the fracture site followed by fixation in plaster or apparatus including the pins or wires

4 Open reduction and internal fixation

The method elected depends upon many factors such as the equipment available, the type of fracture, the age of the patient, and, most important, the preferences and experience of the surgeon Conservative opinion insists that it is best to undertake one of the closed methods of reduction although continued advancement in operative technic has greatly reduced the hazards of open methods [See discussion of operative reduction, Chapter 22 —Ed] The advantages and disadvantages of each of these various procedures will be considered in the separate sections devoted to them

CLOSED REDUCTION BY MEANS OF TRACTION

Treatment of fractures of the shaft of the femur by continuous traction is the most generally applicable method because it requires less specialized operative skill However, while the method is simple, it demands an abundance of careful supervision and patience The mechanics of whatever apparatus is utilized must be thoroughly understood by an attendant who can check the various components of the rigging at hourly intervals during the day Needless to state this service is rarely attainable outside a hospital

Certain general principles are involved and certain equipment is standard regardless of the type of traction utilized Reduction is obtained by the exertion of continuous traction on the distal fragment against the weight of the trunk and upper extremities as counter traction This traction is exerted by means of either (1) adhesive plaster or other adhesive material applied directly to the skin of the leg, or (2) wires, pins or calipers inserted into the bone The patient must be in a fracture bed This may be either a bed especially constructed to prevent sagging of the mattress or an ordinary hospital bed with a board placed between the spring and the mattress An overhead frame is necessary to support the various pulleys and ropes which hold the splint, trapeze, etc The simple Balkan frame is satisfactory, although wooden frames especially adapted to a given type of bed or tubular metal ones have definite advantages Except when the Russell extension type of traction is elected a Thomas, or preferably the Keller Blake half ring modification thereof, with a Pearson attachment for support of the leg must be at hand

As an alternate type of splint to hold the thigh and leg muscles in physiologic balance one may utilize the very satisfactory Braun frame advocated by Bohler This splint is simpler to rig than a balanced suspension apparatus and requires less frequent checking On the other hand it allows the patient less freedom of movement than is possible with the suspension principle In any type of traction one needs a supply of pulleys rope wooden spreaders slings for the splint weights and a trapeze bar In case skeletal traction is to be used one must have special instruments for introducing wires or pins into the bone, and the yokes or stirrups for attachment of the traction lines

The decision between the use of skin or skeletal traction has been simplified since the introduction of Kirschner wires The

hazards of infection and of splitting the bone, which were real when the Steinmann pin and ice tongs were the only means of applying traction to bone, have been almost eliminated by the Kirschner wire. The greater efficiency of the wire in affording a fixed point of traction, and the fact that once introduced it needs no further care, are strong arguments in its favor. This latter point is in contrast to the constant attention demanded by adhesive skin traction methods, the best of which have a tendency to slide on the skin when strong traction is applied. The efficiency of this fixed point of skeletal traction allows the utilization of less weight to obtain and hold the reduction. In cases where there are abrasions, lacerations or other skin lesions of the leg, adhesive traction is impossible and skeletal traction a godsend. By using a wire one may also obtain greater freedom of the knee and a better opportunity for constant observation of the thigh. The necessity for anesthesia in introducing the wire is not a disadvantage since a local infiltration of the site with novocaine is entirely satisfactory.

For these reasons the authors utilize skeletal traction by means of the Kirschner wire in all cases treated by the continuous-traction method, except in children under the age of 12 years. When wires are introduced in children one must be careful to avoid the epiphyses.

Use of Adhesive Skin Traction. Children, adults with weak musculature, and those patients with inflammatory lesions of the skin at the sites of election for insertion of wires may be treated satisfactorily with adhesive skin traction (Fig. 843) and the Thomas or Keller-Blake splint. In undertaking this method of treatment the first important step is to prepare the skin surface of the leg carefully by shaving and cleansing with soap, water, alcohol, and ether. Too vigorous mechanical or chemical treatment of the skin is not advisable because the irritated skin has a greater tendency toward blistering and excoriation beneath the adhesive.

Moleskin adhesive, ordinary adhesive, or glues are the materials available in order of excellence. The moleskin adhesive must

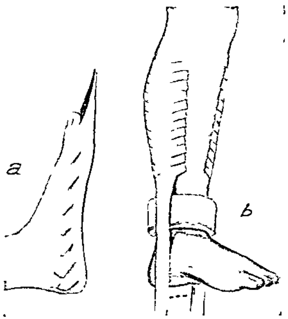


Fig. 843. Application of adhesive skin traction to leg. (a) Footpiece for overhead suspension to prevent footdrop. (b) Traction straps showing formation of traction tapes by folding over of adhesive, feathering of traction straps to provide smoothness of application, malleolar protection by felt, cotton, or sponge-rubber cuff in addition to spreader. Spreader should be placed as near pole as possible (dotted line), and woven elastic bandage should be applied from above cuff to just below upper edge of adhesive. The latter should be always visible so that slipping can be detected when it starts and before strap has pulled completely off. See Chapter 22 for further details.

be applied smoothly and evenly throughout its length, using diagonal cuts on the margins where necessary to insure perfect fit. Even the smallest ridges or creases cause friction on the skin which results in painful blebs. This necessitates removal and reapplication of the tapes with less skin surface

available for the traction and the possible loss of position of the fragments during the change The adhesive bands are three to four inches wide depending on the width of the leg and are best applied as two lateral bands extending from the upper third of the thigh to below the level of the sole of the foot Just above the malleoli each strip is cut medially and laterally for one quarter of its width and the marginal portions below the cuts folded over onto the intact intervening strip Thus is formed a tapelike end which is fastened to a wooden spreader with thumb tacks or by means of buckles The spreader must be wide enough to allow the tapes to clear the malleoli without touching This scheme is better than that of using one continuous strip of adhesive which extends down one side of the leg around the spreader and up the other side in that it is less cumbersome to apply We feel that it is better to bind down the adhesive strips with elastic bandages than with circular or spiral strips of adhesive The use of split traction i e leading two adhesive bands from the thigh and two from the leg is also objectionable The thigh traction bands exert their force on the loose skin of the thigh and on the muscles attached to the pelvis and are thus ineffective in affording traction on the lower bone fragment

After applying the adhesive a Keller Blake splint of appropriate length is passed over the affected leg while traction is maintained on the foot and spreader The ring of the splint is engaged against the tuber ischii and slings are applied to the splint to support the leg and thigh The proper fastening of these slings to the splint so that they conform to the curves of the thigh and leg is an important detail of this procedure The avoidance of wrinkles beneath the knee and the fixation of sufficient padding at mid thigh to restore the anterior bow of the femur are small points not to be neglected

The splint is then suspended by means of a rope which passes through two overhead pulleys and is attached by one end to the ring on the upper end of the splint and by the other end to the foot end of the splint Two weights each one placed on the overhead rope just within the two pulleys serve to balance the leg It is essential to balance the leg accurately in order to permit the patient freedom of motion for nursing procedures and personal hygiene When this system of weights is properly rigged it is amazing to note the amount of body motion attainable with the aid of a trapeze without interference with the positions of the bone fragments [See Chapter 22 for details of suspension —Ed]

A pulley is fixed to the end of the Balkan frame on the side of the affected leg and the traction rope from the spreader is passed over it This pulley should be high enough to accommodate flexion of about 30 at the hip The line of traction must be exactly in line with the shaft of the femur The maximum weight (often 25 pounds) required to reduce the fracture is applied at once If this is not done the progressively increasing strength of muscular contracture becomes increasingly more difficult to overcome in spite of repeated additions of weight and the final total weight required is considerably greater than would have been necessary at the start It may be necessary to elevate the foot of the bed to increase the counter traction in cases requiring heavy traction

The attachment of a trapeze to the Balkan frame above the level of the patient s shoulders is a necessary adjunct for good nursing care and general well being of the patient A strip of adhesive plaster applied to the width of the foot or a boot or sock should be attached to a rope led to a pulley on the overhead frame A small amount of weight on the end of this rope one or two pounds prevents footdrop

During the first 24 hours a check of the length and alignment of the affected limb should be made at intervals of about six hours by actual measurement and by fluoroscope when available Only in this way

can one discover whether there is too much traction as shown by separation of the bone ends, or too little traction as shown by persistence of the overriding. Distraction of the fragments by too much weight is serious if allowed to persist in that it may lead to delayed union If the proper length has been obtained after 48 hours, one may remove from five to ten pounds of weight, leaving just enough to counterbalance the muscle pull. The time here is a generous allowance for the regaining of length, and should represent the maximum. The fewer hours required for regaining length the better. X-ray check-up of the position of the fragments, for length and alignment in the anteroposterior and lateral views, must be done at least once weekly during the maintenance of traction.

There is frequently some lateral angulation of fragments which can be corrected by the use of slings thrown about the thigh and attached to the splint with pins, or to a separate rope and weight directed to the side. Pressure cuffs working on the screw principle are available for correcting these angulations, but they are not recommended because their great force tends to cause too much injury to the soft tissues overlying the bone. Posterior sagging at the fracture site is best controlled by padding placed on the sling at that point. [For general discussion of principles of traction-suspension and of the technic of skin traction, see Chapter 22.—Ed.]

As a rule the patient must remain in this apparatus for from eight to ten weeks. If, by clinical and x-ray studies, union seems firm at that time, the splint is removed. Simple adhesive skin traction of five to ten pounds is placed on the leg, led over a pulley at the end of the bed, and maintained for one week. The patient is encouraged to contract the leg muscles intermittently and to carry out leg and foot exercises of a mild sort. Then for one week more the patient is confined to bed without traction or support of any kind but continuing the active leg exercise. Ten or twelve weeks after occurrence of the fracture, partial weight-bearing in a walking caliper splint with the aid of crutches or in a walking machine is allowed (Fig. 844).

If the fracture is of the transverse type and union appears solid, weight-bearing without crutches is resumed four to six weeks after the patient is allowed out of bed. In the case of long spiral fractures or those with marked comminution, weight-bearing is delayed until there is definite x-ray evidence of solid bony union. This usually requires two to three weeks longer than the transverse type of fracture Light work may be resumed in about 20 weeks and heavy work in about 22 weeks after the occurrence of the fracture.

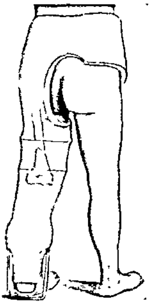


Fig. 844. Walking plaster for fracture held by two single pins incorporated in spica.

The use of physical therapy as so-called after-treatment is often of benefit in rehabilitating patients treated by means of adhesive skin traction. Such physical therapy should be restricted to (1) heat applied to the affected thigh once daily by means of an electric lamp or a warm bath, (2) mild

stimulating massage and (3) perhaps whirl pool baths These measures serve to relieve stiffness and fatigue acquired in the per formance of active exercises The patient must be made to realize that it is monot onous tiresome exercises not the soothing fingers of the masseuse which will restore function rapidly to the affected limb Occu pational therapy is a splendid means of obtaining early restoration of function es pecially among the patients who lack con fidence in the stability of the healed bone [See Chapter 22 for discussion of physical therapy in fracture treatment —Ed]

Use of Skeletal Traction As mentioned previously we prefer skeletal traction to adhesive skin traction for all cases of frac ture of the femoral shaft except in young children Under certain conditions this type of traction is particularly indicated In all well developed individuals with strong mus cles and in cases of compound fracture in which the necessity for wound dressings adds complications skeletal traction is the more efficient In addition to the other ad vantages motion at the knee can be pre served throughout the entire period of treatment

The first instrument commonly used for applying skeletal traction to the femur was the ice tongs or calipers The points of the tongs were driven into the metaphyseal region of the bone just above the upper margin of the condyles The knee was per mitted to move in the yokelike portion of the tongs Because of the relatively large caliber of the soft tissue wounds and the disturbance caused by motion of the points of the tongs infection occurred frequently in using this method Occasionally accidents were recorded in children when slipping of the points of the tongs caused damage to the epiphyses or to the joint structures

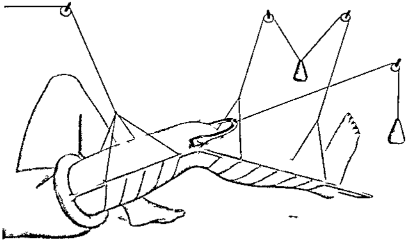


FIG 845 Set up for skeletal traction Instead of a bent Thomas splint a Pearson leg piece on a straight Thomas or a Braun frame may be used The use of a half ring splint with ring in front facilitates nursing See Chapter 22 for additional details as to padding fastening of suspension strips protection against slipping of pin and points to be checked during subsequent supervision

The introduction of the Steinmann pin was a great improvement The points of insertion can be anywhere along the lower part of the shaft instead of just above the flaring condyles and one is certain that there will be no slipping at the point of traction A serious disadvantage to the use of the pin is that if the insertion is not near the middle of the shaft one will occasionally

split the bone. This is particularly true in children and small-boned individuals. Mild infections at the points of penetration of the skin are not uncommon with the use of the Steinmann pins.

The Kirschner wire obviates the drawbacks of both the previously mentioned methods. It is easily applied, most efficient for exerting traction, and causes infection very rarely. We use this method in all cases of femoral-shaft fracture where it is applicable and which require treatment by traction, except in the case of children.

The wire may be inserted satisfactorily with local anesthesia. However, a general or spinal anesthetic is preferable since it allows the operator to perform a reduction at the same time, by manipulating and exerting traction on the leg through the wire, before applying the continuous traction to maintain the reduction so obtained.

The first principle in the application of skeletal traction (Fig. 845) of any sort is that the procedure must be regarded as a major operation. The skin of the leg must be shaved, cleansed, and draped just as carefully as though one were preparing for an open reduction of the fracture. The surgeon must be scrubbed, gowned, and gloved as for a major operation. Only in this way can the risk of infection be certainly minimized.

The authors have used the following technic for inserting Kirschner wires with success. The skin, following preparation, is drawn upward, i.e., proximally, over the point of election and a small incision made through its full thickness, and while traction is being maintained on the skin a trochar is inserted through the muscles to the bone. In order to discover the midpoint of the shaft the trochar can be used advantageously to palpate. Then the trochar is forced through the periosteum and engaged in the outer layers of the cortex manually and the traction on the skin is released. Conscientious adherence to this detail, of pulling the skin upward, will prevent the incidence of pressure necrosis and infection caused by the wire on the tense skin. The wire is then placed in the trochar and drilled through the bone. It may be drilled or pushed through the muscles on the opposite side to the level of the subcutaneous fat. When this point is reached and the skin bulges, it again must be drawn upward as described above and an incision made down to the wire tip. The wire is then forced

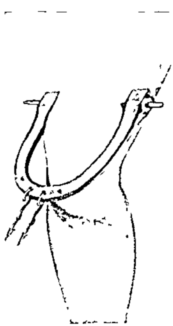


FIG. 846. Close-up of pin and yoke. Felt or cork can be placed between yoke and skin, and corks placed over pin ends.

through so that it projects equally on the two sides, and the yoke or spreader is applied. A satisfactory dressing for the wire wounds consists of gauze covered with collodion. To prevent lateral slipping of the wire in the bone one may thread corks on the wire, forcing them close against the dressings, and then attach the arms of the spreader or yoke outside the corks. By thus avoiding play between the skin surface and the yoke the incidence of infection is also diminished. (See Fig. 846.)

A Thomas splint, preferably the half-ring

modification of Blake to which the Pearson leg attachment has been added is utilized to support the leg It is usually more convenient to apply the splint before inserting the wire The splint is supported in balanced suspension from the Balkan frame and lined and padded as outlined above in the section on adhesive skin traction The thigh is most comfortable and the traction most effective when the hip is flexed to 30 or 40° The knee is flexed sufficiently to allow the leg to parallel the surface of the bed Turnbuckles or slings hold the position of the Pearson splint fixed with relation to the Thomas splint until there is definite evidence of beginning union However the angle of the knee should be changed by 5 to 10° occasionally during the period of fixation At the end of four or five weeks there is usually sufficient fixation by callus to allow mobilization of the knee by balanced suspension of the Pearson splint through a separate rope and pulleys If the cord running from the distal end of the Pearson splint is led upward toward the head of the bed the patient may initiate knee motion by alternately pulling on and releasing the weighted end of the cord Gradually with progressive return of muscle power free motion becomes possible

It is practical and advisable to maintain skeletal traction until union is firm This usually will require from seven to nine weeks *At the end of that time the wire is* removed and the patient exercises in the balanced splints without traction for from a few days to a week Then walking is begun with the aid of crutches or a walking machine and a walking caliper splint The further treatment is similar to that described in the section on adhesive skin traction

The authors feel it necessary to reiterate their preference for skeletal over skin traction and to mention the reasons for this preference The simplicity of application facilitation of nursing care and greater mechanical efficiency are the chief factors in its favor Infection of the wire wounds is a rare occurrence if careful aseptic technic is observed both at the time of insertion and afterward

Furthermore during the maintenance of skeletal traction one may employ physical therapy in an effective manner which is impossible in cases treated by skin adhesive traction Such physical therapy should be intensive It may consist ideally of the exposure of the affected thigh to continuous heat of low intensity as from a 40 watt electric bulb and of short periods of light stroking massage twice daily That this exhibition of physical therapy is beneficial is proved by the diminished healing time of bone and by the more rapid restoration of muscle tone and power in cases so treated These patients treated by skeletal traction usually resume their customary employment one to two weeks earlier than do patients treated by means of adhesive skin traction Disability for light work averages 18 weeks and for heavy work 20 weeks

While this technic is advantageous for all shaft fractures there is one type that involving the lower third or supracondylar region in which it is practically indispensable The flexion of the distal supracondylar fragment by contraction of the gastrocnemius even if of only moderate degree is overcome with great difficulty unless the knee is flexed Sufficient knee *flexion to allow correction of this deformity* is not attainable when skin traction methods are used while with skeletal traction the knee may be flexed to 90° without sacrificing the efficiency of traction force Furthermore one can add an anterior component to the traction force if necessary by altering the line of traction on the wire Thus the tendency to flexion in the distal fragment is more easily overcome [See Chapter 22 for general discussion of technic of skeletal traction and of principles involved —Ed]

[In the use of skeletal traction for fractures of the femur the placing of the pin

or wire through the tibial tubercle instead of through the lower femur is advocated by many men for one or all of four main reasons. (1) Avoidance of all risk of transversing any part of the knee-joint cavity with the pin or wire, (2) minimal risk of knee-joint involvement if the pin or wire hole develops infection, (3) minimal risk of pinhole infection because of a paucity of surrounding soft parts moving about the pin and causing seepage, and (4) ease of application and absence of risk to soft-part structures outside the joint cavity during insertion of the pin or wire.

Against these advantages must be balanced the following disadvantages: (1) Lack of direct control of the distal femur fragment, (2) possible ill-effects of traction on the ligaments of the knee joint, and (3) inability to mobilize the knee joint during the period of traction.

There can be little question of the greater mechanical efficiency of the pin through the femur, or of the value of knee-joint mobilization. The pin through the tibial tubercle requires less skill and technic in insertion, and requires less careful supervision later.

It all boils down to the fact that the pin through the tibial tubercle is a less efficient method, but is less apt to cause trouble if technic and continued supervision are doubtful quantities. The suspension element is the same by either method—the combination of the Keller-Blake splint and Pearson leg piece, or the Braun type of frame (see supracondylar fracture in Chapter 37).

When skeletal traction is used for the typical supracondylar type of fracture, the point of attachment of the Pearson leg piece, or the point of angulation in the Braun frame should be placed *at the fracture site and not at the axis of knee-joint motion.* This materially aids in correcting the backward tilt of the lower fragment (see Chapter 22).

When the supracondylar type of fracture is extremely low, when the lower fragment is comminuted, or when soft-part lesions interdict the use of the pin through the lower fragment, insertion through the tibial tubercle becomes obligatory.—Ed.]

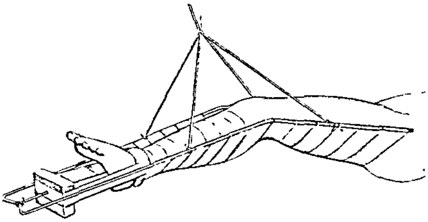


FIG. 847. Hodgen splint traction. Traction straps are fastened to end of splint and pull is exerted by inclining pull on suspension from vertical as indicated. This also exerts a definite lifting action on lower fragment. Leg and thigh should be bandaged into splint.

Other Traction Methods. HODGEN SPLINT. This has been used successfully for the treatment of femoral-shaft fractures by many surgeons. The authors have had no experience with this splint, but feel that it

offers no advantages over the simpler traction methods described above (Fig 847)

Hoke Traction Apparatus This combines traction with fixation in plaster Traction is obtained by means of adhesive strips applied to the sides of the affected leg A double plaster of paris spica is then applied extending from the costal margin to and including the foot on the sound side and to a point just above the malleoli on the affected side The ends of the adhesive strips attached to the injured leg are fixed to the Hoke apparatus and a moderate amount of traction is exerted by means of tightening the screw on the outer side of the instrument When the plaster has dried the position of the fragments is checked and the traction force increased or decreased as indicated [Skeletal traction can be used with the Hoke method See Chapter 35 — Ed]

This scheme is particularly well adapted to the treatment of long spiral fractures which require lateral support as well as traction It allows frequent shifting and turning of the patient in bed or transportation of the patient without incurring the risk of losing the position of the fragments However it is a method which should be used preferably for children or young adults only Older patients do not tolerate prolonged pressure of the plaster casing on their relatively poorly vascularized skin

Six to eight weeks after application one is ordinarily safe in bivalving the plaster to inspect the fracture site and to determine the degree of healing The subsequent management is similar to that to be described in cases treated by immediate reduction and fixation in plaster

Russell Method The Russell method of applying traction suspension for femoral fractures was described in the British Journal of Surgery in 1924 by R H Russell Since that time the excellence of the method for certain types of shaft fractures chiefly those involving the trochanteric region and upper third of the shaft and its relative ineffectiveness in other types have been proved Fractures of the lower third of the shaft are generally managed better by another traction method However this is by no means a rigid rule Similarly fractures in individuals with heavy thighs due either to strong muscles or to obesity are not well managed by the Russell method For children and weak patients as a group the method is well adapted although most children are restless enough to make the maintenance of the traction in proper directions a major nursing problem

A brief outline of the equipment required and the manner of procedure in setting up the Russell traction extension apparatus is as follows

1 A fracture bed with the foot elevated about eight inches on blocks or pins

2 An overhead frame

3 Moleskin adhesive strips which are applied smoothly to the lower leg extending from below the head of the fibula to just above the malleoli The folded lower ends of the adhesive are attached to a spreader just beyond the sole of the foot

4 The hip is flexed to 20 and abducted to about 15°

5 The knee is flexed to about 160° so that the leg is parallel with the bed

6 Soft pillows are placed beneath the calf and beneath the thigh

7 A sling is placed beneath the well padded popliteal space with traction applied to it obliquely upward and toward the foot of the bed via a rope to an overhead pulley making an angle of 120° with the thigh This angle varies somewhat with the individual fracture

8 A single pulley is attached to the spreader beyond the foot and two single pulleys are attached beyond the end of the bed on a level suitable to allow the heel to clear the bed when traction is applied

9 The rope (preferably hatter s cord to minimize friction) is led from the knee sling to the overhead pulley thence to one of the pulleys beyond the bed, thence back to the

pulley attached to the spreader, and finally over the second pulley beyond the bed.

10. A weight of six to twelve pounds for adults, or three to six pounds for children, is attached to the end of the rope.

It is not necessary to anesthetize the patient before applying this traction, although in dealing with muscular adults anesthesia during the initial stage of traction is advantageous. When the apparatus is in place the operator, standing at the foot of the bed, grasps the foot and leg on the affected side and exerts traction of slowly increasing force. When the force is sufficient to reduce and hold the alignment of the fragments a weight, equal in effect to the required force, is applied to the end of the rope. Soft pillows are placed beneath the thigh to prevent sagging of the fragments at the fracture site and beneath the calf to keep the heel raised from the bed.

When this extension apparatus is applied properly, the resultant force is directed, as shown in Fig. 848, directly in line with the shaft of the femur. The importance of arranging the various forces exactly as shown in order to obtain maximum benefits of the method is obvious. One must realize that the double pulley rigging between the foot and the weight supplies an effective force equal to twice the amount of weight at the end of the rope.

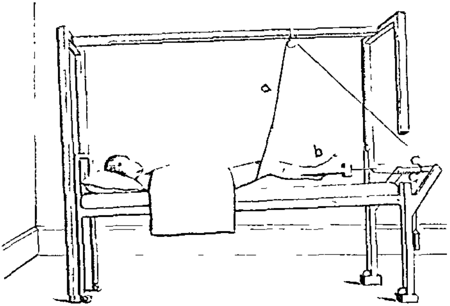


FIG. 848. Russell traction. Thigh and leg should be supported on pillows. A little more flexion of thigh may be needed. Ultimate line of pull is determined by completing the quadrilateral, of which (a) and (b) are two sides. The diagonal from knee to opposite corner of quadrilateral represents line of pull. In constructing this parallelogram of forces it is of course obvious that horizontal sides must be twice the length of upright sides, since a double pull is being exercised on leg-traction straps through pulley arrangement. (See Chapter 22.)

Russell originally advocated maintaining traction for a period of four weeks only. This is too short a time for the average femoral-shaft fracture. We have found it necessary to keep the traction in force for about eight weeks in order to prevent recurrence of deformity. When there is x-ray evidence of firm callus the traction is removed and the patient kept in bed without support for one week. At the end of that

time 9 to 10 weeks after injury walking with the aid of a non weight bearing caliper splint and a walker or crutches is permitted Thereafter the patient s progress is similar to that noted above in the treatment for the skeletal and adhesive skin traction methods

Disability time for light work is about 18 weeks and for heavy work about 20 weeks The similarity in disability times between fractures treated by the Russell method and those treated by the more efficient skeletal traction is due to the difference in the type of fractures treated The Russell method is used in subtrochanteric or high upper third shaft fractures only The bone in this region heals more readily than in the lower portions of the shaft

There is one serious disadvantage of the Russell method it demands frequent inspection and usually adjustment by one who understands the principles involved The instability of the rig and the facility with which a restless or uncooperative patient can disarrange it are exasperating to the resident physicians or internes who should be entrusted with the duty of maintaining the condition of the apparatus Nurses must not be expected to maintain the adjustment unless they have been thoroughly schooled in the niceties of continuous traction therapy

Against this disadvantage one must balance several facts The equipment required is relatively simple involving no special splint or instruments The traction when properly placed is comfortable for the patient because the thigh and leg muscles are held in positions of physiologic balance Nursing procedures are facilitated since the patient can raise himself and turn with the aid of a trapeze just in other types of balanced traction suspension As a final advantage one might add that physiotherapeutic treatments can be carried out without influencing the position of the fragments

[Care must be constantly exercised to avoid two serious complications in the use of Russell traction One of these is peroneal nerve palsy due to pressure by the edge of the supporting sling in the region of the fibular neck The other is pressure necrosis in the popliteal space over the hamstrings In patients who are old dehydrated or debilitated the latter can occur very quickly The peroneal nerve palsy can become established overnight and is very slow to recover —Ed]

CLOSED REDUCTION AND FIXATION IN PLASTER

Reduction of a fracture of the femoral shaft under general anesthesia followed by *immediate fixation in plaster is perhaps the* next most generally applicable method of treatment Campbell in 1925 reported a series of simple fractures treated in this manner with 95 per cent satisfactory results in adults (54 cases) and 97 5 per cent satisfactory results in children (53 cases) These are the excellent results of a surgeon skilled in manipulative reduction and adept in the use of plaster The technic however is relatively simple and may be used safely and with the expectation of good results by the surgeon who treats only an occasional case of this type

In the case seen within 12 hours or later if there is little swelling reduction is performed at once Excessive swelling and ecchymosis necessitate temporizing with the leg elevated in a simple traction suspension apparatus until the swelling subsides The Russell extension apparatus described above is a satisfactory means of supporting the leg until manipulation is performed

Physical therapeutic measures are beneficial in shortening this period of inactivity Such treatment must be as gentle as possible Continuous heat from a 40 watt electric bulb placed 18 inches above the thigh within a covered cradle will stimulate the circulation for the dispersion of hemorrhage and exudates The only other measure which is helpful and innocuous is light stroking massage of the affected thigh The stroking must always begin distally and proceed

proximally—i.e., in the direction of the venous and lymphatic flow. [See Chapter 22 for discussion of timing of manipulative reduction.—Ed]

In carrying out the reduction the patient is placed upon a fracture table with the pubis, adequately padded, firmly against the perineal bar. A general anesthetic is administered. If there is no contraindication we prefer a low spinal anesthesia given with the patient lying on his side on the fracture table before the operative position is assumed. Both feet are firmly fixed to the foot pieces with the thighs in 30° of abduction and the hips and knees flexed to about 45° from the horizontal. The knees are suspended by slings from overhead bars, and the popliteal spaces must be carefully padded with felt. Traction is then applied to both legs by means of the screw extension of the table until shortening of the affected leg has been corrected. Then the operator places both hands on the thigh and by manipulating it in the anteroposterior direction or laterally, as may be necessary, causes the ends of the fragments to engage.

A very expedient method for accomplishment of this reduction is suggested by Key and Conwell. It consists in fixing the unaffected leg as above and resting the knee of the fractured leg on the shoulder of the operator, who faces the patient An assistant exerts pressure on the leg flexed on the operator's back, while the latter exerts traction on the thigh by leaning his body weight back against the flexed leg. Thus the operator is in excellent position to manipulate the fragments with both hands. In this as in other methods of reduction one must employ the principle of bringing the more easily controlled distal fragment into alignment with the proximal fragment.

If the engagement of the bone ends is firm, as proved by lack of shortening and lack of recurrence of deformity on gentle pressure upward on the flexed knee after traction has been removed, the reduction may be considered satisfactory. A fluoroscopic check of the reduced position is comforting but not absolutely essential. After obtaining reduction the position of the thigh must be maintained either manually or more safely and rigidly by means of the slings and extension apparatus of the fracture table during the application of the fixation.

An adequately padded double spica of plaster is then applied extending from the nipple line to the toes on the affected side and to just above the knee on the well leg. Both hips and knees are held flexed 45° and the thighs are abducted about 30°. When the plaster is dry x-ray films are taken.

If the position is satisfactory, this plaster is maintained for two weeks in children and three weeks in adults. At the end of that time the plaster is removed and the hip and knee joints gently manipulated with the patient on the fracture table, in order to minimize later stiffness. At the same time any correction in alignment at the fracture site may be accomplished by manipulating the still soft callus. The legs are then again supported on the fracture table or manually, and a plaster spica similar to the first one is applied with hips and knee flexed to slightly different degrees. This second plaster is maintained for three to five weeks. At the end of that time the plaster is bivalved and the fracture tested for evidence of union both manually and by x-rays. If union has progressed sufficiently the plaster is not reapplied, but the patient is kept in bed without support for one or two weeks, depending on the degree of healing, the status of muscle tone, and the general physical well being. During this period active exercises of the leg are enforced and physical therapy is administered. In the average case walking is allowed with the aid of a walking caliper splint and walking machine or crutches about ten weeks after the fracture occurred. Four to six weeks later the splint is discarded, but the crutches are maintained. As soon as the plaster has been discarded physical therapy in the nature of

(1) heat lamps or warm baths (2) whirl pool baths and (3) massage is helpful in restoring muscle tone and strength In the later weeks occupational therapy will be invaluable in reconditioning joint motion and muscle power

Full weight bearing is resumed about 20 weeks after the fracture was sustained It is advisable to obtain x rays at intervals of 10 to 14 days during the first few weeks of weight bearing in order to detect any tendency toward shortening or angulation at the fracture site before gross deformity occurs

Disability time for fractures treated by reduction and immobilization in plaster is longer than for the traction methods Light work is usually resumed 24 weeks and heavy work 26 weeks after the occurrence of the fracture This longer disability time is due to the inability to speed the healing process and maintain muscle tone by physio therapeutic measures and active exercises while plaster is in place

AMBULATORY TREATMENT

Several ambulatory methods for treating fractures of the shaft of the femur have been advocated during the past few years The results obtained by those who have perfected the rather specialized technics involved certainly justify the added labor incurred at the time of reduction

The procedure described by Roger Anderson or some modification thereof seems most efficient Two steel pins are inserted through both the upper and lower fragments All pins are inserted from the lateral aspect The uppermost pin is directed obliquely in a distal and medial direction from the central point of the greater trochanter and the lower of the two upper pins is directed upward and medially into the shaft from a point about 4 to 5 cm below the first Both pins transfix the shaft completely their points projecting just above and below the lesser trochanter Two pins are similarly inserted through the lower fragment at an angle to one another piercing the shaft from the lateral aspect in the same manner as the upper pin

Special yokes or bracket are attached to each set of pins An alternate procedure consists in using only one steel pin or a Kirschner wire to pierce the lower fragment This wire extends equal distances on either side of the thigh Having introduced the pins or wires reduction may be accomplished manually or by utilizing the traction devices of an ordinary fracture table or by means of the specially designed reducing apparatus The latter provides arms and yokes to which the pin brackets are attached Traction elevation angulation and rotation in the various planes required can be obtained by manipulating the various turnscrews of the splint so that an anatomic reduction is attained When the position of the fragments has been checked by x rays a plaster casing incorporating the projecting pins is applied from the crest of the ilium to a point two inches below the knee The plaster is cut out over the patella and behind the knee joint to allow free motion of the knee After the plaster has set the leg is removed from the apparatus

[In place of the plaster encasement an arrangement of bars and nut clamps can be utilized to hold fixed the reduction obtained by the machine For a general discussion of pins and plaster and pins and apparatus reduction and fixation and of its technic see Chapter 22 where the use of the Roger Anderson Stader and Haynes apparatuses are illustrated Ed]

The patient is encouraged to walk with crutches without weight bearing as soon as the reaction to operation has subsided Gradually during the ensuing two weeks weight bearing may be instituted As soon as there is x ray evidence of callus formation many of the patients are able to walk with only the aid of a cane The plaster or fixation apparatus is maintained for from 8 to 12 weeks depending upon the rapidity

of healing. Generally, comminuted and long spiral fractures require a longer time than anatomically reduced transverse fractures.

The theoretical advantages of this method of treatment are obvious. In fractures which would be difficult to hold reduced by simple traction methods or by fixation in plaster, the points of skeletal fixation afforded by the pins serve to allow accurate reduction and to hold the fragments rigidly when encased in plaster. This method is particularly well adapted to fractures of the immediately subtrochanteric region with the flexed, abducted and externally rotated upper fragment, and also to cases of fracture of the supracondylar area with a sharply flexed lower fragment. The early resumption of motion of the hip and knee is beneficial in that it is prophylactic against the muscle atrophy and joint stiffness which frequently follow methods of treatment which involve immobilization of these joints. Perhaps the greatest factors in favor of this procedure are the shortened period of hospitalization and the shortened disability time which appreciably lessens the financial burden for the patient.

Despite these definite advantages of the ambulatory method, we are reluctant to recommend it for general use. The specialized instruments required are not always easily available on the average surgical service. A more important consideration is the mechanical skill required to utilize the equipment properly. Facility in manipulating apparatus of this sort comes only with frequent use, and the skill of even the adept is often heavily taxed to obtain the optimum results. [See Chapter 22 for general discussion of this point.—Ed.] The disability time for light work averages 16 weeks and for heavy work 18 weeks. These periods are shorter than in cases treated by traction or immobilization in plaster because hip and knee motion and a fair degree of muscular activity of the thigh, leg, and foot are performed in walking during the period of fixation. The muscle atrophy resulting from the other methods of treatment is eliminated to a large extent.

OPEN REDUCTION AND INTERNAL FIXATION

Although there is a growing tendency to employ open reduction in fractures of the shaft of the femur, the consensus is overwhelmingly in favor of attempting reduction by a closed method primarily. Failure to obtain reduction after a fair trial by means of traction and manipulation usually indicates the interposition of soft parts between the fragments. Such a situation demands prompt action in the nature of an open reduction to free the fragments in order to prevent delayed or nonunion. The presence of displaced intermediary fragments which cannot be controlled, and the occasional refractory spiral fracture are complicated conditions which are best handled by open reduction. In all fairness to the method one must admit that in many large clinics, particularly those associated with large industrial organizations, open reduction and internal fixation is the method of choice. Furthermore, the results obtained in terms of anatomic alignment, firm fixation, and early resumption of function when this type of treatment is successfully carried out certainly justify the enthusiastic claims of its adherents. [See Chapter 22 for discussion of this whole subject.—Ed.]

Optimum Time for Operation. The decision to utilize the operative treatment should be reached as soon as possible in order to save extra hospitalization for the patient. The most auspicious time for open reduction, as for any method of reduction, is within one to two hours after the occurrence of the fracture, before excessive hemorrhage has occurred into the tissues and before onset of muscle spasm and infiltration. If it is necessary to delay operation because of the presence of shock, or in order to evaluate or treat a systemic condition of the patient, this delay should be

as short as possible The aim of operative reduction is to debride the affected area of blood clot and devitalized muscle and to effect rigid fixation before the phase of organization of the clot occurs Once it occurs the extensive infiltration of blood about the site of fracture causes pressure necrosis and devitalization of the soft tissues Such a poorly vascularized area is slow in healing and prone to become infected and in these cases one must wait until absorption and organization of the hemorrhage and subsidence of edema is well under way before venturing to inflict further injury on the tissues by operative procedures

Skin Preparation In cases operated on as emergencies one must shave the thigh carefully and then begin the skin preparation with a grease solvent such as benzene and follow with an ether wash The usual antiseptic solutions or the soap and water technic may be used Cases which are to have a delayed operation should have a careful preparation of the entire thigh with soap and water alcohol and ether in that order at least once on the day preceding operation The thigh is then carefully covered with sterile towels which are bandaged firmly in place until the patient is on the operating table At that time the final skin preparation is done Too rigorous skin preparation which might create excoriations or abrasions of the easily damaged skin in the operative area must be avoided

General Technic of Operation The technic employed in the open reduction of fractures must be most careful in regard to asepsis A strict Lane technic is perhaps the ultimate in bone surgery In most hospitals unfortunately the special training of nurses interns residents and staff members which is essential to form teams capable of carrying out Lane technic is impossible from an economic point of view However a modified Lane technic to the extent of touching the operative area as little as possible with the fingers can be maintained without great difficulty We have found this latter plan eminently satisfactory The scalpel used for the skin incision is discarded and a clean one used for dissection of the deeper tissues Towels should be carefully clipped to the skin edges with large Michel clips so that wound contamination from the skin surface is prevented

The incision is usually made on the anterolateral aspect of the thigh utilizing the plane between the vastus lateralis and rectus femoris to approach the bone It should be long enough to permit easy exposure of the fracture site Reduction is carried out by traction with the aid of levers and bone holding clamps in a manner employing the maximum of mechanical efficiency and a minimum of tissue trauma A suitable clamp or clamps should then be used to hold the fragments rigidly in the reduced position while the fixative agent is applied

We feel very strongly about the advantages of rigid internal fixation and employ it in all cases of open reduction even though the reduced fragments tend to stay in position Internal fixation properly applied should afford an equal or greater sense of security against recurrence of deformity than the most efficient form of external fixation A number of different types of fixation are available Steel plates Parham bands screws bolts or wire may be used effectively while catgut and fascial strips should not be used because they cannot produce rigid fixation and are not permanent Our preference for an internal splint of the femoral shaft is a six hole Sherman type of plate made of vitallium There are several stainless steel materials available which are also satisfactory We prefer not to use the old standard vanadium steel plates and screws because of their tendency to corrode and break in the medium of the tissue fluids It may be well to emphasize the important fact pointed out by Venable and Stuck that plates and screws or any other combination of metal fixative mate

rials must be made of the same metal. Failure to observe this fundamental rule will result in the establishment of an electrical current between the dissimilar metals, due to a difference in the electrical potential. This electrolytic action causes corrosion of the metal concerned with loosening of screws in the bone and consequent loss of reduction, or at least of rigid fixation The possible adverse influence of the electrical current on the healing bone is a second serious consideration. [See Chapter 22 for discussion of this point.—Ed.]

Attention to certain technical details will greatly facilitate the operation of plating fractures. Adequate exposure of the fracture site to permit easy visualization and manipulation with a minimum of trauma is a primary requisite of open reduction. When reduction has been accomplished it is advisable to clamp the plate firmly to the aligned fragments before drilling the bone to make screw holes. The so-called "free hand" drilling with the plate placed loosely on the bone may be necessary in some cases due to anatomic complications in certain types of fractures. However, this latter method greatly increases the difficulty of properly aligning the plate and screws. Before applying the plate the periosteum should be raised from the bone in such a manner that the muscles remain attached to the periosteal flaps, thus insuring its blood supply. No more periosteum should be raised than is necessary to accomplish reduction and to accommodate the plate. The vascular periosteal flaps are then sutured over the plate.

The caliber of the drill chosen should be just less than that of the screw to be inserted to insure a firm grip for the screw. The correct-sized drill for the standard screw has a diameter of 3/32 inch—a No 32 Brown-Sharp drill is ideal. The drill should be directed at right angles to the shaft, passed through the near and far cortices, stopping just short of the periosteum of the distal cortex. When the drill is about to emerge from the far side of the distal cortex, it will bind slightly for about one-quarter turn. If one stops drilling at that point the lunge through the soft tissues which often follows complete penetration of the bone is avoided. Also, if the drilling is stopped at this point one can then measure the length of drill buried in bone and thus have an accurate idea of the length of screw required. The screws, of course, are of the self-tapping machine variety They must be inserted accurately at right angles to the plate and shaft in order to prevent the development of shearing forces which might lead to loosening of the screws or even to fracture of the plate.

In order to eliminate these shearing forces, the insertion of one or more free screws, of the same metal as the plate and its screws, across the fracture line has been suggested and used for some years by Clay Ray Murray. These cross-fixation screws are inserted in a horizontal plane relative to the screws of the plate. Separate fragments large enough to afford a grip may be anchored in place by these free screws. [See Chapter 22 for detailed discussion of technic of internal fixation.—Ed.]

After the internal fixation has been completed and the wound closed, the affected leg should be placed in a Thomas splint in balanced suspension as described above in the section on skeletal-traction methods. The suspension is continued with the knee held in a flexed position on the Pearson attachment for about four weeks. At that time, if there is x-ray evidence of callus formation, the knee is mobilized and active motions of the joint in flexion and extension and swinging of the hip in abduction and adduction are encouraged. After the eighth week the splints are removed and the patient remains in bed for one or two weeks without support. Finally after ten weeks, walking with the walking caliper splint and crutches, or the walking machine, is permitted. The future progress depends on the degree of healing and the strength and ambition of the patient.

This scheme of postoperative treatment seems more advantageous to us than the alternate one of encasing the affected leg in plaster for six or eight weeks By fixation in plaster one approximates the rigid fixation obtained by the ideal plating operation but we consider the early institution of active exercise permitted by internal fixation one of the chief arguments in favor of this type of treatment It not only maintains the muscle tone of the leg and avoids joint stiffness but also accelerates the healing process by promoting the revascularization of the affected area

TREATMENT OF COMPOUND FRACTURES OF SHAFT OF FEMUR

The treatment of compound fractures of the femoral shaft as of other long bones is a controversial subject Since it is treated exhaustively elsewhere in this book we shall merely outline briefly procedures which we employ

The main question at issue is when to debride Every case deserves at least a limited local debridement of the skin wound even though this appears to be but a tiny puncture The practice of debriding or not debriding on the basis of whether the compounding has been caused by the bone from within or by the blow of an external object is to be condemned The decision regarding the mode by which the wound occurred is almost always based on speculation rather than fact Too often in debriding the insignificant puncture wound one discovers a tract contaminated with gross dirt leading down to the bone and not infrequently in such circumstances bits of grit will be found on the roughened ends of the fragments Therefore one can avoid the potential risk of infection only by thoroughly debriding every case The methods employed in debridement are treated extensively elsewhere in this text [See Chapters 22 and 23 for extensive discussion of compound fractures —Ed]

However the problem of primary closure or drainage of the wound invites debate There is no doubt that if one were sure that all infected and devitalized tissue had been removed primary closure of the wound would be the procedure of choice And furthermore most of the cases in which one would feel sure of perfect debridement would heal by primary intention However because the status of the wound cannot be determined with absolute certainty at the time of operation we feel that the only fair decision is to drain every such wound The drainage is accomplished with petrolatum gauze packed loosely into the wound In addition in cases which appear to be clean deep tension sutures are placed through the skin and muscles at the time of debridement and tied loosely over a gauze dressing The wound is inspected after five days and if there is no evidence of infection the petrolatum gauze pack is removed and the wound closed by tying the previously placed sutures

There are some who advocate the reduction and fixation of the fragments by means of plates and screws or other metal devices after debridement The arguments in favor of this practice are that if the wound heals by primary intention the reduction is insured and if infection should ensue the rigid fixation of the fragments will not encourage it as would motion of the fragments which would occur if supported by any other less rigid form of splinting This reasoning is logical but not convincing enough to lead us to recommend internal fixation of these compound fractures The introduction of foreign bodies into a potentially infected wound seems to violate one of the cardinal principles of surgery [See Chapter 22 for full discussion of this point —Ed]

Within recent months the introduction of external fixation in cases of compound fractures has been acclaimed by men working in this line and their results seem indeed gratifying However until more experience

has been gained and a further period of time allowed to evaluate the end-results we hesitate to recommend this as a procedure of choice. The inability of clinicians to obtain the necessary equipment for this type of treatment has narrowed the field of men experienced in this type of management.

After débridement and packing of the wound skeletal traction in a Thomas splint with Pearson attachment, according to the technic described in the section on skeletal traction, affords an excellent method of fixing these fractures.

In our experience, infected compound fractures are best treated by the Orr method or some modification thereof.

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37

Fractures and Dislocations Involving Knee Joint

R ARNOLD GRISWOLD M D

SUPRACONDYLAR FRACTURES OF FEMUR

The chief characteristic of supracondylar fracture of the femur is posterior (flexion) displacement of the distal fragment This is caused by the powerful pull of the calf muscles (Fig 849) The position of muscle equilibrium in this fracture is flexion of the knee at an angle of from 45 to 90°

Reduction is usually accomplished by traction in flexion although open reduction may be necessary Fixation after reduction is maintained by a plaster spica continuous traction or internal fixation Traction in any case is applied by Kirschner wire or Steinmann pin through the upper tibia rather than through the distal fragment of the femur Shortening is due to contraction of the longitudinal muscles (hamstrings and quadriceps) which insert in the leg For this reason traction applied to the tibia exerts its force more directly and efficiently on the muscles than when it is applied to the femur

When normal length is restored in the proper position of muscle equilibrium the intact ligaments of the knee will float the fragments into position There is no danger of overstretching these ligaments since the real traction force is exerted on the muscles Once these are pulled out to normal length the amount of force necessary to restore the relationship of the fragments is very slight

Reduction by manual pull and manipulation without the aid of skeletal traction is difficult and is so often unsuccessful or only partly successful that its use is not advised If it has to be used because skeletal traction is not available the manual traction should be made on the *leg* with the knee well flexed while an assistant exerts forward lift on the lower femur in the popliteal space Even should reduction be so accomplished the chance of maintaining it without the aid of a wire or pin fixed in the immobilizing plaster would be discouragingly small

REDUCTION AND FIXATION IN PLASTER

Before removing the first aid splint a careful examination is made of the nerve and blood supply distal to the fracture to rule out damage to the popliteal vessels and nerves which may be injured by the flexed distal fragment If such damage is revealed by the examination operative exploration is indicated and if the damage is to the vessels it is a matter of urgency This examination may conveniently be done while the x rays which have been taken in the splint are being developed General anesthesia may be employed or a low spinal

anesthetic is administered or 20 to 40 cc. of 2 per cent novocaine is injected into the hematoma at the fracture site. [See Local *Anesthesia Technic, Chapter 22.—Ed.*] The two latter methods are preferable to general anesthesia.

The patient is placed on a fracture table and the first-aid splint removed, while an assistant maintains steady manual traction on the foot until mechanical traction is applied by the table mechanism. If there is sule with 1 per cent procaine introduced through a 26-gauge needle. An 18- or 20-gauge needle attached to the aspiration syringe is passed through the anesthetized tissue into the joint, taking care not to lacerate the cartilage. Aspiration is carried out with the least possible motion of the needle. Near the end of aspiration, it is helpful to have an assistant compress the joint with his hands to force the fluid to the region of the needle. After removal of

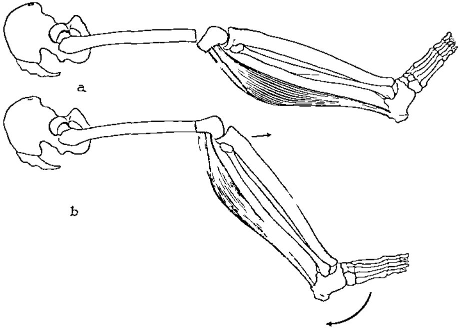

FIG. 849. (a) Typical deformity in supracondylar fracture produced by action of gastrocnemius. (b) Correction of deformity by traction applied to upper tibia and flexion of knee.

hemarthrosis, as frequently occurs following laceration of the suprapatellar pouch, the blood is removed by aspiration.

Aspiration of Knee Joint. Strict attention to asepsis is essential, although extensive skin preparation and draping are unnecessary. The joint is most easily entered anteriorly, either lateral or medial to the patella. The usual site is at the lateral distal margin of this bone. An area 2 inches in diameter centered over the selected point is painted with an appropriate skin antiseptic. The skin and soft tissues along the needle tract are infiltrated down to the cap- the needle, momentary massage with an alcohol sponge helps close the needle channel and prevents leakage with danger of infection going down the tract.

The skin is carefully prepared for insertion of the Steinmann pin at the level of the tibial tubercle. If spinal (or general) anesthesia has not been used, the tissues from skin to periosteum on both sides of the tibia are infiltrated with 1 per cent novocaine. A 3/32- or 1/8-inch stainless-steel pin, 6 to 7 inches long, is inserted directly through the skin, transverse to the bone, at the level of the tibial tubercle, one finger-

breadth anterior to the fibula The Steinmann pin is preferred to the Kirschner wire for fixation in plaster The inherent rigidity of the pin permits firm skeletal fixation without the use of wire tauteners, and it is less likely to break under strain than is the wire No incision is made and care is taken not to pull or displace the skin [See general discussion on use of pins and wires, Chapter 22 —Ed]

With a small hammer or metal mallet the pin is driven through until it projects an equal distance on each side of the bone The small cones of skin which have followed the pin at entrance and exit are smoothed out No dressing is used about the pinholes A Bohler type stirrup is attached to the pin The manual traction is now transferred from the foot to the stirrup

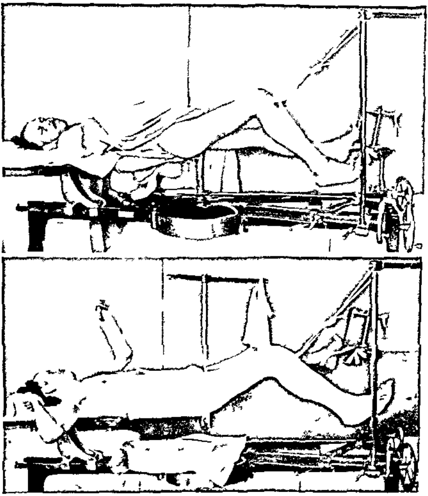

FIG 850 (*Top*) Position of patient on fracture table for reduction of supracondylar fracture
FIG 851 (*Bottom*) Plaster spica applied for fractures of lower femur

The perineal post of the table is put in place so that it rests against the ischium of the well side, and the foot of the well side is fixed firmly to the footpiece of the table While a steady pull is maintained in the line of the shaft of the femur, the stirrup is elevated until the hip is flexed 30 to 60°

The foot and leg are allowed to hang free, the foot dropping into plantar flexion and thereby relaxing the calf muscles. The stirrup is then attached by strong cord to the elevated footpiece of the table. Mechanical traction is applied in this position until shortening is overcome. The freely hanging leg usually overcomes the angular deformity, but occasionally it must be flexed still more, or extended slightly (Fig. 850). Residual corrections of position are made by direct manual molding of the fragments. Traction is then reduced slightly to allow firm end-to-end abutment of the fragments and to guard against distraction.

The position is checked by anteroposterior and lateral x-rays, or the fluoroscope. If satisfactory position is shown, a plaster spica is then applied from the costal margin to the toes of the affected side as follows: The anterior superior spines and the sacrum are covered by patches of silence cloth or thin felt which are held in place by snugly fitting stockinet or a circular layer of flannel bandage extending from the xiphoid to the trochanter. If the bandage is used it should be wrapped tightly about the pelvis in figure-of-eight fashion to compress the lax buttocks. A padded roll is snugged to the tuberosity of the ischium, similar in size, consistency, and function to the ring of a Thomas splint or walking caliper brace. This roll, resting against the tuberosity of the ischium and the origin of the adductors, transfers the stress of longitudinal muscle pull to the pelvis. The pad is made by rolling tightly an 8 by 10 inch piece of silence cloth or thin felt about the middle 8 inches of a three-foot length of muslin bandage. This roll is completely covered by a spiral of one-inch adhesive tape which compresses it to the size and firmness of a Thomas splint roll. It is applied with its center over the tuberosity of the ischium, the posterior end lying in the gluteal fold and the anterior end crossing the hip joint. By pulling firmly outward and upward on the ends of the bandage, the pad is fitted snugly beneath the tuberosity and the origin of the adductors.

Circular plaster bandages are applied snugly to the trunk and pelvis and molded about the crests and spines of the ilia. Anterior and posterior plaster splints are molded to the skin from the toes up over the pelvic portion of the plaster. The edges of these are clipped opposite the pin to allow close fitting. The region of the hip is strengthened by four or five spica-wise splints which also support the ischial pad. The whole is covered with circular plaster, one or two turns of which are looped around each end of the pin to fix it firmly in the spica.

While the plaster is setting, an assistant should apply constant pressure on both sides of the pelvis to mold the plaster to the crests of the ilia and the hollows between the crests and the trochanter (Fig. 851). Trimming of the spica is done to uncover the upper abdomen and allow free motion of the uninjured thigh.

By this time, the plaster has set sufficiently for the traction to be released and the stirrup removed. The ends of the pins are protected by corks (those from ether cans are convenient), held in place with one or two layers of plaster bandage. The patient is then turned on his abdomen and trimming of the posterior part of the spica carried out. It should be cut to the top of the cleft of the buttocks and for about 2 inches to each side along the cleft to facilitate use of the bedpan If trimmed too widely over the buttock, bulging with irritation from the edge of the spica will occur. Unless properly tended in the first 48 hours, these spicas may crack at the hip or knee. Therefore, in turning these patients, they should be rolled toward the well side with adequate support for the limb in plaster. Better yet, if enough help is available, turning is accomplished by lifting the patient straight up, turning him in the air, and then laying him down.

Angles at the hip and knee should be

supported by pillows After 48 hours of drying a properly constructed spica should not crack For an adult of average size 12 to 14 hard surfaced 6 inch bandages are sufficient to make a spica which will weigh about 12 pounds

TRACTION SUSPENSION TREATMENT

Continuous traction is used when other injuries preclude the above procedure, or when comminution or obliquity of the frag ments makes it seem likely that plaster

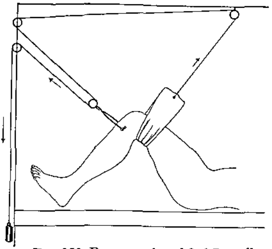

FIG 852 Diagram of modified Russell traction used for fractures of condylar region

fixation may not suffice Neither skin trac tion nor Russell traction is satisfactory in the reduction of these fractures and their use is not recommended The patient in his emergency splinting is placed on a prepared fracture bed with overhead frame Anes thesia is obtained preferably by the injec tion of 30 or 40 cc of 2 per cent novocaine into the hematoma about the fracture site

The first aid splint is removed and while manual traction is maintained, a stainless steel pin 6 or 7 inches long is driven through the tibia at the level of the tubercle under local anesthesia as described above under reduction and fixation in plaster The Bohler stirrup with a pulley attached is ap plied to the pin A well padded canvas sling 8 by 24 inches is passed under the knee The ends of this sling are tied to a long traction rope This rope passes through a pulley on the overhead frame on a level with *the patient s pelvis then to one 2½ to 3* feet directly above the foot of the bed then to the pulley on the stirrup and back to another pulley alongside of the one 2½ to 3 feet above the foot of the bed A weight of 15 to 20 pounds is suspended from this rope (Fig 852) The apparatus is adjusted by raising or lowering the pulleys at the foot of the bed and moving the pulley over the pelvis forward or backward so that the knee is lifted and is flexed at least 45° and the heel just clears the bed A wide strip of adhesive is accurately molded to the sole of the foot and attached by a rope running through a pulley at the top of the frame to a light weight which should be just suffi cient to hold the heel off the bed and to prevent excess toe drop It must not be heavy enough to stretch the calf muscles

The foot of the bed is raised 12 inches on blocks to increase the counter traction af forded by friction and the weight of the body Fig 852 shows the similarity of this type of traction to ordinary Russell trac tion The following differences are appar ent (1) Skeletal traction is applied to the upper tibia (2) the line of pull on the sling is considerably cephalad, rather than slightly caudad and (3) the resultant of the lines of force is almost vertical The sling is necessary not only to support the knee but to lift the distal fragment into proper alignment Raising or lowering the foot is possible and permits change in the angulation of the distal fragment

Anteroposterior and lateral x rays are taken or a fluoroscopic check is made every few hours and the apparatus adjusted until correct position has been obtained The amount of weight is then reduced about one half As is the case with most fractures reduction should be obtained at the earliest possible moment For this reason it is better to use a large amount of weight early

and reduce it later, than to keep adding weights over a period of days. Traction-suspension is maintained until the end of three or four weeks, by which time healing of oblique or comminuted fractures has usually progressed enough so that a spica may be applied. If plaster fixation has been delayed on account of other injuries, the spica may be applied whenever these injuries permit. The patient is transferred as gently as possible to the fracture table without changing the relative positions of the leg, thigh, and body. A plaster spica is applied as described above.

Open Reduction and Fixation

When the above procedures fail to secure good position of the fragments, open exposure and direct reduction are indicated. High supracondylar fractures may be approached by the same route as is used for fractures of the shaft of the femur; viz., an anterolateral incision which separates the vastus lateralis from the rectus and which splits the vastus intermedius. However, this incision necessarily stops short of the upper margin of the patella and does not give good exposure of a short distal fragment. A better exposure for the low fracture is obtained by a lateral incision upward from the level of the joint line over the lateral condyle for about six inches. This incision splits the fascia lata and vastus lateralis and exposes the condyle well.

If closed reduction on the fracture table has failed, open reduction should be carried out at the same sitting without changing the patient's position if possible. If traction-suspension has been tried, the patient is transferred to a fracture table and strong traction is applied by means of the pin through the tibia with the hip and knee flexed as described above. No tourniquet is used.

After the requisite careful preparation of the skin, the extremity is draped for operation, paying particular attention to fully covering the traction pin and stirrup which are necessarily near the field. If the stirrup has not been previously sterilized and kept sterile, it is well to cover it with one or two layers of towels wrung out in bichloride of mercury 1:4,000, or a similar germicide, before applying the final drapes. A 6- or 7-inch incision is made on the thigh from the joint line up over the lateral condyle. Towels are carefully clipped to the wound edges and the customary careful ritual of bone surgery carried out from then on. The fascia lata and lower posterior portion of the vastus lateralis are generously split in the direction of their fibers and the soft tissues are gently cleaned from both fragments in front and behind sufficiently to give a clear view of them. When good exposure of the fracture has been obtained, the need for more traction is often evident. This is easily obtained from the mechanical-traction element of the table, and assists the operator in his application of direct instrumental manipulation to the fragments.

When good position has been obtained by this combined method, the traction is decreased to allow firm abutment of the fragments. In most cases, they will remain firmly in position Rarely will comminution or smooth obliquity of the fracture surfaces necessitate internal fixation if the pin through the tibia is used, and it is often difficult to fix a plate to the short distal fragment without endangering future function of the knee. Stainless-steel wire passed through the fragments is probably the method of choice if any form of internal fixation is used. The direction of these sutures is determined by the plane of the fracture surface. If the fracture is sufficiently oblique, two or more screws may be inserted across the fracture plane. An unusually long distal fragment may, of course, permit a metal plate to be applied without encroaching upon the joint.

The wound is closed in layers with fine interrupted silk sutures and sealed with a thin layer of silver foil. A light dressing is taped in place and a plaster spica applied

as described heretofore without changing the position of the limb The interrupted silk skin sutures need not be removed until the spica comes off [See also Chapter 36 for treatment of this fracture —Ed]

In suitable cases, where study of the x rays would seem to indicate that good rigid internal fixation can be accomplished, the plaster may be omitted if such rigid fixation is accomplished In this case, post operative active mobilization in a balanced suspension apparatus is logical However

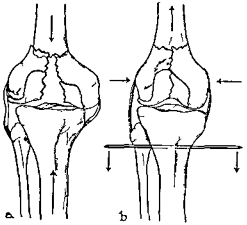

Fig 853 (a) Mechanism of T and Y fractures of femur (b) Mechanism of reduction of T and Y fractures by traction and compression

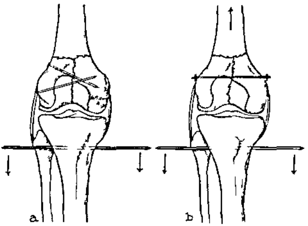

Fig 854 (a) Fixation of T and Y fractures by nails (b) Fixation by a transcondylar bolt

this should not be used unless all the conditions laid down in the general section on operative reduction are strictly met [See Chapter 22 —Ed]

T AND Y FRACTURES OF FEMORAL CONDYLES

In these fractures, in addition to the supracondylar break, there are one or more vertical fracture lines into the joint, often with more or less comminution As a result of the fracturing force or muscle pull, the distal end of the femoral shaft may be driven between or over the condylar fragments into the joint (Fig 853 A) The principles involved and the methods employed in treatment of T and Y fractures are the same as those employed for supra condylar injury in restoring the relationship of the condyles to the shaft In addition the following measures must be taken to replace the condyles in relation to each other and to the knee joint

Reduction and Fixation in Plaster

The patient is placed on the fracture table and the procedure described above for reduction and fixation of supracondylar fractures is carried out After the gross displacement has been corrected by traction and manual manipulation, a Scudder or Forrester modification of the carpenter s C clamp is used to mold the condyles into proper position This clamp has large, padded faces which are curved to fit the condyles, and it is applied over a layer of felt The faces are applied to the sides of the knee in a position appropriate for molding the displaced fragments

The clamp is then tightened slowly until the fragments can be felt to move into position (Fig 853 B) It is important that the pressure should be maintained for only a few seconds at a time, in order to avoid

injury to the soft tissues. Placing the clamp on the uninjured knee and measuring the distance between the faces is a convenient way to determine that sufficient replacement has been accomplished.

Anteroposterior and lateral x-rays are taken. If these show satisfactory position, a spica incorporating the traction pin is applied from the costal margin to the toes, as described for simple supracondylar fracture.

Traction-suspension Treatment

As an alternate method, continuous traction-suspension may be carried out. The procedure is similar to that employed in the traction-suspension treatment of supracondylar fractures, but, in addition, the C clamp is used as described above, in order to replace and impact the condyles with due protection of the soft parts.

Open Reduction and Fixation

If the x-ray check-up does not show satisfactory replacement of the condyles by the use of either of the preceding methods, open reduction and fixation is necessary. This is carried out immediately, if possible, without changing the patient's position on the table if manipulative reduction has failed. The shaved skin about the knee is prepared in the usual careful manner for surgical operation. Sterile drapes are applied with especial attention to covering the traction stirrup and pin which are necessarily near the field of operation. One or more towels soaked in bichloride of mercury 1:4,000 are snugly clipped just below the knee to completely cover the traction equipment. A 5- or 6-inch longitudinal incision is made on the lateral side of the thigh, extending upward from the joint line. The fascia and vastus lateralis are split to the bone in the direction of their fibers. Exposure of the condyles and fracture site is obtained by stripping the soft tissues from the bone and retracting.

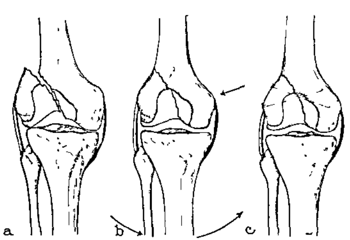

Fig. 855. (a) Displacement of fragment in fracture of one condyle. (b) Replacement by forcing knee into varus so that lateral ligament draws condyle downward. (c) Fixation of condyle by nails or screws.

The fragments are levered into position under direct vision and, if necessary, palpation. Two or three vitallium or stainless-steel nails at different angles are used to transfix the condyles to prevent subsequent spreading (Fig. 854 A). An alternate method is to pass a long drill across the condyles to the medial side where a stab wound is made over the point of emergence of the drill. A 3/32- or ⅛-inch stainless-steel bolt is threaded through the drill hole from the medial side as the drill is removed. A long Sherman screw with a washer and nut

makes an effective bolt Another substitute for a bolt is a long threaded Austin Moore hip nail which has had the unthreaded portion clipped off A nut is used on each end of this The condyles are pressed together as the nut is tightened laterally The excess bolt is clipped off and the lateral wound closed in layers with fine silk (Fig 854 B) One or two skin sutures suffice for the small medial wound Both wounds are sealed with silver foil and thin dressings applied A spica is applied incorporating the tibial traction nail as previously described

FRACTURE OF A SINGLE CONDYLE

This fracture is commonly due to leverage exerted in such a manner that the knee is forced into valgus or varus splitting off the lateral or medial condyle The separated condyle is usually displaced proximally (Fig 855 A) The principle of replacement is to use the intact collateral ligament to draw the displaced condyle downward by forcing the knee into varus for fractures of the lateral condyle and into valgus for those of the medial condyle

Reduction and Fixation in Plaster

Under low spinal anesthesia by preference otherwise under general anesthesia the patient is placed on the fracture table and the first aid splint removed The knee is examined to determine that the collateral ligaments are intact If they are torn traction should not be applied The perineal post is put in place and the feet attached firmly to the footpieces of the table Only enough traction is applied to steady the patient on the table The knee is aspirated (see p 1029) to empty it of the large effusion of blood which is common to these fractures A wide muslin or flannel bandage is passed around the knee Firm traction is made by an assistant on this bandage in a lateral direction if the lateral condyle is fractured or in a medial direction if the medial condyle is fractured This traction throws the knee into varus or valgus increasing tension on the lateral or medial ligaments respectively and pulling the condyle downward (Fig 855 B) Residual molding is carried out manually and the condyles pressed firmly together with the C clamp A plaster spica is then applied as previously described the varus or valgus position being carefully maintained until the plaster has set

Open Reduction and Fixation

If this maneuver does not succeed in replacing the fragments or if the collateral ligaments are torn open fixation is carried out The approach to the lateral condyle is the same as that described above for T and Y fractures The approach to the medial condyle is by a 4 or 5 inch incision upward from the joint line over the internal condyle The vastus lateralis or medialis is split and the dissection carried close to the bone until the fragment is well exposed The condyle is replaced in correct position under vision and fixed with two or three vitallium or stainless steel nails (Fig 855 C) The wound is closed as before and a plaster spica applied

AFTER CARE OF SUPRACONDYLAR AND CONDYLAR FRACTURES

After the plaster has set young muscular patients or even elderly ones with sufficient ambition may be allowed up on crutches If the flexion of the knee is not too great a walking heel is applied to the spica The type of spica described is light enough so that it is not a great burden If the patient is not ambulatory on account of weakness or other injury muscle setting exercises are insisted upon These should be carried out 15 or 20 times at least three times a day and should include contraction of the quadriceps and flexion and extension of the toes

If the patient is ambulatory even the joint capsule and synovia enjoy painless motion notwithstanding the fact that the bones making up the joint do not move to

any perceptible degree. This is clearly evident from an analysis of the muscular attachments to the capsule of the knee. The quadriceps tendon, which is inserted into the patella and through it to the patellar tendon, forms the anterior ligament of the joint capsule. Tendinous expansions from the vasti and the iliotibial band form the medial and lateral retinacula which fill in the intervals between the anterior and collateral ligaments of the capsule. Posterior to the collateral ligaments are expansions from the sartorius and semimembranosus to the capsule on the tibial side. A few fibers from the latter muscle join with the tibial collateral ligament. Posteriorly and laterally the gastrocnemius and popliteus arise in part from the capsule and its oblique popliteal ligament. The tendon of the biceps femoris divides to embrace the fibular collateral ligament

The capsule of the knee is thus made up or acted upon in its entirety by muscle origins or insertions. Contraction of the quadriceps causes slight sliding of the patella and motion of the entire anterior synovia by means of the retinacula. Posteriorly and on the sides, the other muscles noted may be made to repeatedly tense and relax the capsule, thus preventing gluing together of the synovia and the capsular fasciae.

At the end of four weeks from the time of injury, the pin may be removed from the tibia. This is done by cutting out a disk of plaster 2 inches in diameter about each end of the pin. The uncovered pin end and skin on one side is cleaned and an antiseptic applied. It is extremely important that all crusts, plaster, etc., be removed from the pin and the surrounding skin to prevent drawing such foreign bodies into the pin tract. Tincture of iodine, merthiolate, or mercresin are suitable antiseptics for the skin and pin. The other end of the pin is then grasped with ordinary pliers, and the pin pulled out. It has been our custom to inject 2 or 3 cc. of 3 per cent tincture of iodine through the pin tract. This seems to hasten healing. Light dressings are applied and the areas recovered with plaster.

At the end of eight or ten weeks, depending upon the age of the patient and the progress of healing as shown by x-ray, the spica is removed. The older patients require the longer period of immobilization. Exercises for ankle, knee, and hip as well as heat and massage are instituted at this time. As soon as extension of the knee is possible, which is after a few days if adequate exercise has been taken in the spica, a Thomas walking caliper splint is fitted. This should be worn for an additional six to eight weeks. When hospitalization is not a factor, and when firm internal fixation has been obtained by operative means, it is sometimes possible to dispense with the spica. In this case, the limb is suspended from a fracture frame in a Thomas splint with Pearson attachment. This method permits very early active and passive motion of the joint. It does, however, require longer hospitalization, and the end-result, as to function, is not superior to that obtained by the plaster technic, if adequate exercise has been taken in the spica. The claim is made that open reduction, followed by early active mobilization in balanced suspension, secures more rapid return of function and therefore results in shorter disability time, although the degree of function finally regained may be the same as that attained in the immobilized cases.

Fractures with hemarthrosis—i.e., those which involve the joint, such as T and Y fractures—show a relatively slower return of function and a greater degree of impairment than do those which do not involve the joint, even when perfect anatomic position has been obtained. The older the patient, the more marked is the delay in recovery.

As in all fractures, the extent and length of disability depends upon a number of factors, including (1) the age of the patient,

(2) the severity of the fracture (3) the accuracy of reduction and (4) the involvement of the joint Roughly one may say that in these cases light work should be possible in not less than four months or more than six months and heavy work in six months to a year

SEPARATION OF LOWER EPIPHYSIS OF FEMUR

The deformity in this injury is usually anterior displacement of the distal fragment The distal end of the shaft projects

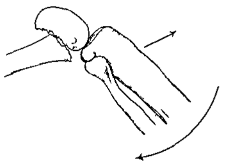

Fig 856 Typical displacement in separation of lower femoral epiphysis and forces required for reduction

into the popliteal space and may cause severe damage to structures in that space Examination will reveal whether or not this damage requires surgery Immediate reduction is imperative The method employed is traction plus flexion the mechanics of which are similar to those employed in transcondylar extension fractures of the humerus (Fig 856)

Closed Reduction and Fixation

Low spinal anesthesia gives the best relaxation of muscles but general anesthesia can be used For convenience in obtaining counter traction the patient is placed on the fracture table with the perineal post in place and the well foot fixed to the foot piece With the injured knee flexed about 45°, the operator applies strong manual traction to the flexed leg while an assistant supplies lifting support under the thigh As the muscles relax under traction flexion of the knee is increased to an angle of 90° or beyond A soft crunching sensation accompanies reduction X ray or fluoroscopic check up is made and if reduction is complete a plaster spica is applied in 45 to 90° flexion of the knee the angle chosen being the minimal one at which reduction can be maintained

This simple maneuver may not suffice in cases more than a few hours old In such cases a pin or wire is passed through the upper tibia and traction applied in flexion on a fracture table as described for supracondylar fractures Further flexion of the knee under strong traction will then usually replace the fragments

Open Reduction and Fixation

When the injury is several days old the fragments may have already stuck In this case open operation is carried out forthwith on the fracture table without decreasing the traction as soon as it is evident that manipulation with pin or wire traction will be unsuccessful Because of the great danger of operative surgery to the epiphyseal line open reduction is indicated only after adequate attempts at closed reduction have failed A generous lateral incision is made as for exposure of T and Y fractures Smooth long finger retractors of the type used for McBurney appendiceal incisions are applied one in front of the distal fragment the other behind the proximal fragment Gentle pull in opposite directions on these retractors while strong traction is maintained will slide the fragments by each other with a minimum of trauma to the epiphyseal tissues Care should be taken that no rotary or lateral displacement occurs during this maneuver No instrument should be passed between the fragments to lever them into place as this will damage the epiphysis and predispose to early fusion and cessation of growth For the same reason no internal fixation

is used. Traction is reduced somewhat to allow the fragments to press tightly together, the wound is closed in layers as previously described, and a plaster spica applied in flexion, including the pin or wire.

At the end of four weeks the plaster and the wire may be removed and motion of the knee begun. Crutches may be used after six weeks and unaided weight-bearing started at the end of eight to ten weeks.

Although growth disturbance does not ordinarily follow carefully performed closed reduction in fresh cases, its incidence is sufficient, particularly in the delayed or operative cases, to require semi-annual x-ray examinations for several years, so that appropriate corrective measures may be instituted early.

[The implication that growth disturbance after carefully performed closed reductions on fresh cases of separation of the lower femoral epiphysis is unusual will not be concurred in by many. The consensus would seem to be that 30 per cent show such growth disturbance after closed reduction, and a considerably higher percentage after open reduction. The feeling in general would seem to be, in this as in other epiphyseal separations, that operative reduction should certainly be avoided if possible. It is generally felt that both operative reduction and repeated attempts at closed reduction are unjustified if 50 to 60 per cent apposition of the surfaces can be attained by the first two attempts, provided the epiphysis is more than three years from time of expected closure. Growth correction of deformity is marked in these cases if the epiphysis is viable, and in the event that growth disturbance occurs, or that deformity is not completely corrected, an osteotomy after closure of the epiphysis will take care of the situation. See discussion of epiphyseal injuries, Chapter 22.—Ed.]

FRACTURES OF PATELLA

The patella is a sesamoid bone in the extensor tendon of the knee. The principles of treatment of fractures of this bone are concerned with the integrity of the extensor apparatus of the knee. From a mechanical and functional standpoint, the problem is that of repair of a ruptured tendon rather than reduction of a broken bone. Fractures without separation of the fragments, that is without rupture of the extensor apparatus, require little more treatment than relaxation and rest of this mechanism. Those with separation require operative repair of the extensor apparatus.

Fractures Without Separation of Fragments

There is usually considerable effusion of blood into the joint in these fractures. This blood is removed as completely as possible by aspiration. Two or three large, firm rubber sponges are then snugly fixed over the extended joint with elastic bandage to prevent reaccumulation of blood. A 2-inch strip of moleskin adhesive is applied from the knee to the lower third of the leg, one laterally and one medially, leaving about 8 inches of free adhesive at the lower end. A single snug layer of cotton sheet wadding is applied from the lower third of the leg to the groin. A circular plaster-of-paris encasement is applied over the sheet wadding. The free ends of the adhesive are turned up over the lower end of the encasement and secured with another layer or two of plaster bandage. This adhesive will prevent slipping of the plaster when the patient is allowed up. Rest in bed is advisable for about ten days in order to relieve all strain on the quadriceps group. Extension of the knee is maintained by the plaster and further relaxation of the extensors is obtained by elevation of the extremity to about 30° so that the thigh in its plaster encasement is flexed on the pelvis.

After ten days, the patient may be ambulatory in the plaster, with weight-bearing allowed. This protection should be maintained for about three weeks from the time of injury. It is then replaced by an elastic

support and active motion of the joint is started

Passive motion is not indicated but other physiotherapeutic measures such as massage whirlpool baths and various forms of heat may be useful Weight may be borne on the extremity as soon as the patient is up but crutches should be used to protect them against mishap such as sudden unguarded flexion The crutches and elastic support should be discarded at about the sixth week after injury Light work may be begun at this time and heavy work is usually possible by the twelfth week

Fractures with Separation of Fragments

Many of these fractures particularly those of dashboard origin are complicated by lacerations of the overlying skin which may extend into the fracture site and the joint These must be considered separately

Fractures Without Injury to Overlying Skin Like all open reductions of fractures operations for fracture of the patella should be performed as early as possible General or low spinal anesthesia is administered Operation without a tourniquet is to be preferred If a tourniquet is used it should be loosened before the wound is closed so that exact hemostasis may be obtained A generous transverse incision is made over the gap between the fragments extending well around the sides of the knee so that adequate exposure of the torn vasti may be obtained The skin edges are completely covered by pads or towels clipped to the wound edges by skin clips

The fascia is then incised on both sides to expose the tears in the lateral expansions Loose pieces of bone are removed and discarded Liquid and clotted blood is carefully removed from the joint by suction and irrigation with normal saline The joint cavity is inspected for bony fragments The shredded edges of the torn anterior capsule are trimmed close to the fracture edges to prevent interposition between the fragments A strong braided silk mattress suture Champion No 12 is inserted in the lateral expansion of the tendon on each

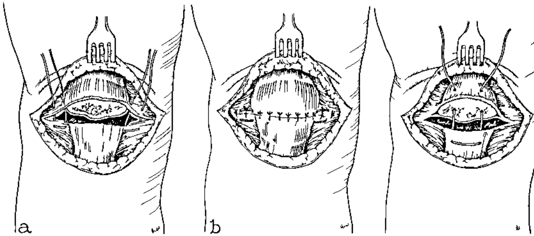

Fig 857 (*Left* and *Center*) (a) Insertion of braided silk sutures in lateral expansions for fractures of patella Notice that these sutures are close to bone and do not include synovia (b) Suture completed with C silk in anterior capsule and lateral expansions These should also be mattress sutures

Fig 858 (*Right*) Suture of patellar tendon to bone after excision of distal fragment or fragments as suggested by Thomson

side, closely hugging the bone (Fig. 857 A). This suture includes only the tendinous structures and not the synovia and does not enter the joint. The fragments are held accurately approximated by hooks or tenaculum forceps and the mattress sutures tied. The lateral tears and the anterior capsule are approximated with interrupted C silk sutures laid 0.5 cm. apart (Fig. 857 B).

If, as frequently happens, the distal portion of the patella is badly fragmented, it may be removed and the patellar tendon approximated to the large proximal fragment by braided-silk sutures, Champion No. 12, extending through drill holes in the bone (Fig. 858), as recommended by Thomson. These drill holes pass from the fractured surface just anterior to the cartilage to the upper anterior surface of the patella. On a few occasions when the whole bone was reduced to a number of small fragments, we have removed them all and sutured the quadriceps to the patellar tendon with heavy silk, Champion No. 12 (Brooke). In either case, the lateral expansions are also carefully repaired with fine silk. The fascia and skin are closed with A silk, and sterile dressings are applied. Over these is placed a large pressure dressing of sheet wadding from the midthigh to the midleg, held with elastic bandage. The extremity is elevated in bed for from 48 to 72 hours. After this time active motion is encouraged to the limit allowed by the dressing. The skin sutures are removed at the end of a week, and the patient allowed up on crutches at the end of two weeks with a pressure dressing or elastic support to prevent extreme flexion. This support is discarded at the end of the sixth week.

Crutches may be discarded by the eighth week. Except for passive motion, the usual physiotherapeutic measures are useful. Light work is usually possible by the tenth or twelfth week, and heavy work by the end of the fourth or fifth month.

Many surgeons add direct suture of the fragments by wire, silk, or heavy chrome to the repair of the tendinous structures. The method of Magnuson* using 22-gauge stainless-steel wire prevents gaping of the articular portion of the fracture which may follow anterior wiring. Circumferential wiring has been followed by necrosis of the patella. I see no advantages in the method of Ober. [Ober's procedure entails exposure of the fracture site as here described, with the lower end of the rectus femoris tendon well exposed. A flap of the superficial half of this tendon is outlined, extending upward from a base at the superior border of the patella. It should be about one and one-half inches longer than the patella and about three-quarters of an inch wide. It is dissected free and split longitudinally to make two tendinous strips attached to the upper border of the patella. Two large drill holes are then placed longitudinally from the upper border of the reduced patella to the lower border through both fragments, one on either side of the midline of the patella. The strips of tendon are then threaded through these holes and pulled taut at the lower openings, crossed over one another, and sutured to one another and to the adjacent aponeurosis on either side of the patella. The tears in the medial and lateral expansions are repaired as well.

Complete excision of the patella for all fractures showing separation of the fragments is recommended and used by a number of men in this country and abroad. The procedure is done through a longitudinal midline or parapatellar incision, the rectus tendon being sutured after removal with a little overlap if quite lax. The advantages claimed are earlier resumption of active motion, shorter convalescence, no residual disability, and freedom from risk of subsequent arthritic difficulty secondary to irregularity in the under surface of the patella, and degenerative changes in its articular cartilage.—Ed.]

* See Fig. 214, p. 275, Magnuson's Fractures, 4th ed., Philadelphia, J. B. Lippincott Co.

Fractures with Superficial Lacerations or Abrasions Even the slightest laceration or abrasion over the knee tremendously increases the danger of infection if operative treatment is carried out If seen in the stage of contamination before proliferation and the penetration of bacteria into the tissues have occurred immediate emergency operation is indicated Abrasions should be thoroughly but gently scrubbed with soap and water and thoroughly disinfected Lacerations should be cleaned, excised, and thoroughly irrigated before proceeding with operation as above If the injury is excessively dirty or is over eight hours old, operation is contraindicated until the wounds have completely healed and epithelialized This restriction holds true even for the most minor lacerations or abrasions In this case, the extremity is fixed in extension as for nonoperative treatment A window is made in the plaster for the treatment of wounds *Operation must be deferred until all scabs are off and epithelialization is complete* Surgery is then carried out as for a fresh closed fracture

Fractures with Extensive Laceration and Compound Fractures These cases require immediate emergency surgery to prevent infection The object is to convert the contaminated wound into a clean wound before infection occurs Careful attention to details will insure success Under adequate anesthesia preferably spinal the extremity is thoroughly scrubbed with sterile green soap and water from midthigh to midcalf The operator should be capped and masked and should wear sterile gloves for this part of the procedure as for the operation proper A sterile scrub brush and repeated changes of soapy sponges are used Scrubbing should be done centrifugally from the wound taking care that no dirty washing fluid contaminates the wound This can be accomplished by plugging the wound superficially with sterile gauze However thorough cleansing of the skin right up to the wound edges must be done and thorough irrigating of the laceration with green soap and water is indicated in dirty wounds This stage of cleansing requires at least ten minutes by the clock to be effective [Many

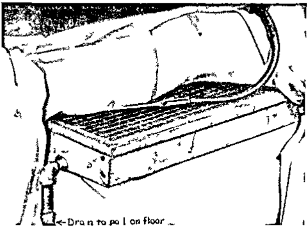

FIG 859 Drainage pan for debridement devised by Henry Marble of Boston This is a metal pan 8″ x 18″ by 2½″ deep with a removable ¼″ mesh hardware cloth top Sterilized pan is placed beneath wound Irrigating fluid is caught by pan and conducted through spout and tube to bucket on floor

men dislike the use of a brush because of possible skin trauma and prefer to use gauze sponges altogether.—Ed.]

Without removing the last soapsuds, the field is centrifugally shaved with a sterile razor. Excess soap is removed with sterile water and the skin is then scrubbed with three changes of ether sponges. Any good antiseptic may, if desired, be painted or sprayed on the skin, but not into the wound. The field is draped for surgery after gown and gloves have been changed. The further débridement and cleansing of the wound is carried out under a constant stream of sterile saline, 5,000 to 6,000 cc. of which will be used. It is well to make provision for this fluid by placing a Kelly pad under the field or by using the pan described by Marble (Fig. 859). This is a galvanized iron pan 8 by 18 inches by 2½ inches deep with a removable ¼-inch mesh hardware cloth top. A rubber tube may be attached to a spout at one end of the pan to carry irrigating fluid into a bucket below the table. This sterile pan is placed directly beneath the extremity so that all fluid from the wound is caught in the pan and does not soak the drapes and patient. The nozzle of the irrigating hose is placed in the depths of the wound (if the joint is open, deep into the joint beneath the fragments) and a constant flow of fluid maintained upward and outward from the depths of the wound. This detail is important.

Excision is then commenced. The laceration is circumscribed by an incision 5 mm. from its border. This is carried through skin, fat, and fascia to the extensor aponeurosis, excising the wound en bloc. Fragments of soiled or contused tissue are carefully excised with the knife, as are loosened fragments of bone. Torn shreds of aponeurotic tissue are floated up by the saline, making their recognition and removal easy to carry out. All floating shreds are removed, since they have been deprived of blood supply. This procedure must be carried out most thoroughly and carefully, removing all devitalized tissue, dirt, and clot.

When the operator is thoroughly satisfied that he has rendered the wound as free from bacteria, dirt, and injured tissue as possible, the question of repair comes up. If the wound is less than six or eight hours old, has been transported without contamination and is not excessively dirty, primary repair may be carried out as for the closed fracture. Instruments, gowns, gloves, and drapes should again be changed before this stage of the operation is done. It is advisable to dust the joint and the wound surfaces with 5 Gm. of sulfanilamide crystals before closure. [See Compound Fractures, Chapter 22.—Ed.]

If, in the judgment of the surgeon, the wound is too old, is too contaminated or is one in which adequate cleansing has been impossible, repair of the extensor apparatus is deferred. In this case, only the skin is closed with interrupted fine silk, and treatment is carried out as described above for fractures without separation (Bohler).

Three or four weeks later, when the wound has completely healed and the skin is normal, operative repair of the extensor apparatus is done.

In neglected compound fractures seen 12 hours or more after injury, or those so soiled that adequate cleansing is impossible, the procedure recommended by Campbell is useful. Débridement is not done in cases seen 24 hours or more after the accident and in which the clinical signs of infection are present, as distinct from contamination. No closure is used except the loose approximation by a towel clip on either side of the patella. The bone fragments are approximated by manual external pressure and large towel clips are inserted through the skin above and below the wound on each side of the patella. The points of these clips engage the fragments or the lateral aponeurosis close to the bone. When closed, they prevent wide separation of the fragments but allow adequate drainage of the

wound Secondary repair is carried out at a later safe date At this time all scar tissue is excised from between the fragments and the operation completed as for primary closed fractures

Ruptures of Extensor Apparatus

Avulsion of Tibial Tubercle This injury usually occurs in adolescents as the result of sudden excessive quadriceps contraction If displacement is slight immobilization for four to six weeks in a walking circular plaster (knee extended) will suffice This plaster is similar to that described for the closed treatment of fracture of a tibial condyle

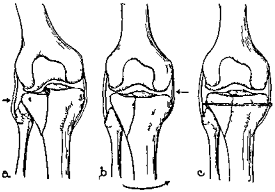

Fig 860 (a) Fracture of lateral condyle due to force exerted against lateral side of knee as by an automobile bumper (b) Reduction by forcing knee into varus (c) Fixation by bolt through condyles

Cases with displacement require open fixation A transverse incision 3 inches long is made over the tubercle The patellar tendon and tubercle are exposed as is the crest of the tibia A transverse drill hole is made through the crest just below the tubercle and a braided silk suture passed through this hole and the tendon As the suture is *tightened* the avulsed fragment is fitted into its place The wound is closed and plaster applied as for the closed treatment or active mobilization carried out as following the suture of fracture of the patella If the plaster is used crutches are discarded as soon as the patient has enough self confidence to dispense with them Otherwise their protection is necessary to prevent mishaps such as sudden unguarded flexion In either case since only the extensor and not the weight bearing apparatus is involved the patient may bear some weight from the first and should be bearing full weight by five or six weeks Physiotherapy is useful during this period and until full function is regained Since these patients are usually in the younger age group full work is permissible at about eight weeks

FRACTURES OF CONDYLES OF TIBIA

Fracture of One Condyle

Fractures of a single condyle are usually due to forced varus or valgus of the knee as from an automobile bumper striking the lateral aspect of a knee (Fig 860 A) In this case if the medial collateral ligament *does not tear* the lateral condyle of the femur is forced against the lateral tibial plateau crushing it downward and outward It may separate as a single fragment but more often it is comminuted and impacted Prognosis and treatment depend upon the degree of malalignment of the tibial plateaus Cases with no spreading and ⅛ inch or less depression of the condyle require only aspiration of the knee a pressure dressing and abstinence from weight bearing for from six to eight weeks

The patient may be up on crutches without weight bearing after the first few days and may begin to bear some weight after six to eight weeks but unaided weight bearing should not be permitted for about 12 weeks Heat and massage are useful during this period An elastic support for the first few weeks will usually prevent the re accumulation of fluid but if this occurs the joint should be aspirated Light work may be started at the end of the third or fourth month, and heavy work by the sixth

month. Those with displacement of one-quarter to three-eighths of an inch require more active treatment.

[Many men use as their criterion the amount of lateral instability present rather than the measured depression of the condyle, and reserve for the preceding group those cases showing less than ten degrees of possible abduction of the leg on the thigh with the knee in extension and subject all cases showing more than ten degrees of such instability to the forms of treatment which follow.—Ed.]

Closed Treatment. Under low spinal, local, or general anesthesia the patient is placed on a fracture table with slight traction applied to both legs. The joint is aspirated of all blood. A 6-inch muslin bandage is passed about the medial side of the knee and strong lateral traction applied as for fracture of the lateral condyle of the femur (Fig. 860 B). This throws the knee into varus, and the tension of the lateral ligament tends to pull the condyle upward. If the fracture is of the medial condyle, the traction is, of course, made in the opposite direction to throw the knee into valgus. Molding of the residual deformity is carried out with the C clamp described in treatment of femoral condylar fractures. This clamp is applied to the condyles and tightened until impaction is felt and the distance between the two heads of the clamp is the same as may be obtained on the normal knee. The clamp is immediately released upon correction of deformity so that damage to soft parts may be avoided.

X-ray check of the position is made. If this is not satisfactory, open reduction is required, as described below. In most cases, however, the x-ray shows good position and a nonpadded plaster is applied from perineum to toes, maintaining a varus position.

This plaster includes at its upper end a padded roll similar in size, consistency, and function to the ring of a Thomas splint or walking caliper brace. This roll, resting against the tuberosity of the ischium and the origin of the adductors, transfers some of the stress of weight-bearing to the pelvis. The pad is made by rolling tightly an 8 by 10 inch piece of silence cloth or thin felt about the center of a three-foot length of muslin bandage. This roll is completely

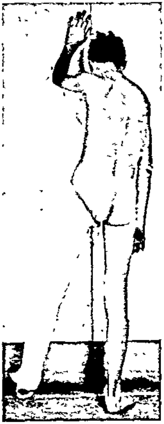

FIG. 861. Circular plaster for fractures of upper tibia. Shelf of plaster holding perineal pad in place is shown. Walking iron shown is too long. (Courtesy, Griswold, R. A.: Amer. Jour. Surg. 32: 254.)

covered by a spiral of one-inch adhesive tape which compresses it to the size and firmness of a Thomas splint roll. It is applied with its center over the tuberosity of the ischium, the posterior end lying in the gluteal fold and the anterior end crossing the hip joint. By pulling firmly outward and upward on the ends of the bandage, the pad

is snugly fitted beneath the tuberosity and the origin of the adductors

Anterior and posterior splints are applied from the pad downward to the toes These splints are accurately molded to the contours of the extremity particularly over the bony prominences of the knee and ankle They are then covered with circular turns of plaster The upper circular turns incorporate the pad and are snugly molded on the medial side to form a shelf like structure which holds the roll firmly against the ischium Five 6 inch hard surfaced bandages are sufficient for this type of plaster (Fig 861)

Open Reduction Fractures which do not respond to conservative measures for reduction or in which the tibial plateau is depressed more than three eighths of an inch require open operation especially if there is marked comminution and spreading

A long incision is made beginning lateral to the patella at the level of its upper margin extending downward over the lateral condyle medial to the fibular collateral ligament of the tibia to a point 3 inches below the joint line This incision is carried through the fascia and capsule into the joint

The soft tissues over the upper end of the tibia are dissected up to expose the origins of the extensors from the patellar tendon well around the lateral aspect of the condyle to the tibiofibular articulation The interior of the joint is washed clear of blood and clots The lateral semilunar cartilage which is often found to be badly damaged may be freed from its attachments and removed to give a good view of the articular surface of the tibia If it is damaged it has to be removed If it is undamaged it usually interferes sufficiently with adequate handling of the fracture to warrant its routine removal The common extensor origin is stripped laterally from the region of the tibial tubercle exposing the anterior surface of the condyle but taking care not to deprive too much bone of its blood supply The condyle and its articular surface are usually found to be more badly comminuted than would appear from the x ray

With a narrow periosteal elevator the depressed fragments are lifted into place and fitted together in their normal plane The fragments of cancellous bone below the plateau are pressed and molded upward and inward to support the articular surface which should be made smooth This sometimes leaves a gap at the lower portion of the condyle due to crushing and impaction of the fragments If this is found to be the case the incision is lengthened or a separate incision is made over the upper portion of the shaft of the tibia A small wedge shaped graft is removed from the crest and impacted into the gap below the condyle A long drill is passed from the lateral side of the condyle parallel to the tibial plateau traversing the head of the tibia emerging on its medial side through a small wound made over the point of the drill As the drill is withdrawn a long 3/32 or ⅛ inch stainless steel bolt follows the drill A nut tightened down on this bolt presses the fragments firmly together (Fig 860 C)

The principal wound is closed in layers with interrupted fine silk and the stab wound with one skin suture and covered with a light dressing A nonpadded plaster is then applied in varus as for the non operative treatment

If the condyle consists of only one fragment as it rarely does two stainless steel nails driven across at different angles may suffice instead of the bolt If the fracture involves the medial condyle the same procedure is carried out on the medial side and the extremity put up in valgus

After care The patient may be allowed up on crutches without weight bearing as soon as pain will permit Muscle setting exercises are encouraged from the start At the end of four weeks a walking heel may be added to the plaster and weight bearing permitted The plaster remains for 10 to 12 weeks however so that most of the strain

of weight-bearing is borne by the ischial pad. At the end of this time it is removed. If the patient has been active in plaster, knee motion will be quite good and will rapidly improve. If firm fixation has been attained by an open reduction, the plaster may be omitted, and balanced suspension utilized. Active motion of the ankle, knee, and hip may then be allowed shortly postoperative. In no case, however, should unaided weight-bearing be permitted in less than 12 weeks, since the soft cancellous bone involved consolidates slowly and may undergo deforming compression. Crutches may be used for from two to three weeks after removal of the plaster and physiotherapy (except passive motion) instituted if it is needed. In no case should light work be permitted in less than 12 weeks and it is often not advisable before four to six months. Heavy work may be possible in from six months to a year.

T and Y Fractures of Condyle

These fractures are usually the result of force exerted in the long axis of the leg, driving the tibial shaft up between the condyles, which are forced laterally (Fig. 862 A). Reduction requires traction to restore length and manipulation and compression to force the condyles together.

Closed Treatment. Under general or spinal anesthesia the patient is placed on the fracture table and the well foot firmly fixed to the footpiece. The joint is aspirated of all blood. A 3/32-inch Steinmann pin 6 inches long is driven through the tibia two to three fingers above the medial malleolus, just in front of the fibula, according to the technic described for supracondylar fractures. This pin is attached by a Böhler stirrup to the footpiece of the table. Strong traction is applied to the straight leg until the length of the extremity is restored. The squeezing effect of the taut ligaments and fascia aids in replacing the condyles. Manual manipulation and compression with the C clamp, as for fractures of the femoral condyles, complete the reduction (Fig. 862 B). The position is checked by x-ray and a circular plaster with ischial pad is applied, as described for fractures of a single condyle, firmly incorporating the pin.

Since both condyles are involved, neither plaster nor internal fixation will prevent

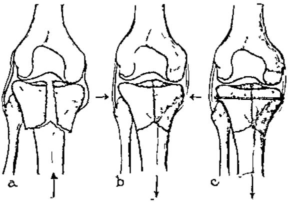

Fig. 862. (a) Mechanism of T and Y fractures of tibial condyles. (b) Reduction by traction and compression. (c) Fixation of fragments with bolt.

pressure on the fragments by the femoral condyles as the result of longitudinal muscle pull. Therefore, continuous traction, either fixed or balanced, is necessary. Fixed traction may be obtained by passing a Steinmann pin through the femoral condyles before applying the plaster. Balanced traction is obtained by a weight of 10 to 12 pounds attached by appropriate stirrup and pulley arrangement to the pin in the distal tibia, with the plaster encasement suspended by weights from an overhead frame.

Traction-suspension Treatment. If, for any reason, primary fixation in plaster is not indicated, traction-suspension may be used. Primary closed reduction and fixation in plaster may be contraindicated by other injuries which take precedence in treatment, or by extensive soft-tissue damage which it is feared may result in excessive swelling. The procedure is the same as above, up to the application of plaster. At that point, unrelaxing manual traction being maintained, the patient is transferred to a

fracture bed, and the extremity is placed in a balanced Thomas splint with the knee fixed in slight flexion Ten to fifteen pounds traction is then applied to the pin, replacing the manual traction, to maintain the position

Open Reduction and Fixation If the conservative procedures outlined above are not immediately effective open reduction is indicated and should be done at the same sitting if possible

While strong traction is applied by means of the pin through the lower tibia on the fracture table as described above, the knee is prepared for operation A four inch incision is made over each condyle midway between the respective lateral ligaments of the knee and the borders of the patellar tendon These are carried to the bone and exposure of the articular surface of the tibia obtained If either meniscus is damaged it is removed The condylar surfaces are aligned by leverage and manipulation, assisted by increasing or decreasing the traction When alignment is obtained a long drill is passed through both condyles parallel to and ¾ to 1 inch below the articular surface As the drill is withdrawn a 3/32 or ⅛ inch stainless steel bolt is passed along the drill tract and the nut tightened to firmly compress the condyles The excess bolt is clipped off the wounds closed in layers with silk, and sealed with silver foil (Fig 862 C) A circular plaster is applied and traction continued as for closed reduction

If fixed traction through both the femur and tibia has been used, ambulatory treatment may be carried out as soon as pain will permit Weight bearing on the walking iron is permitted at four weeks If traction suspension with or without plaster has been used, it is maintained for eight weeks An advantage of traction suspension without plaster is the opportunity to institute early active motion in traction, although at the risk of some displacement Whatever method has been used, the Steinmann pins are removed and a fresh plaster applied at eight weeks and weight bearing continued or started as the case may be This cast remains for about four weeks after which graded weight bearing with crutches may be started Physiotherapy and an elastic support are useful at this time At the end of 16 weeks the patient should be walking without support

Again the time away from work and the amount of permanent disability are increased by involvement of the joint The patient s age the severity of the fracture and the accuracy of replacement all play a part in the estimation of disability Light work should be possible in from four to six months and heavy work in from six months to a year

DISLOCATIONS AT KNEE

Dislocation of Patella

Acute traumatic dislocation of the patella may be (1) lateral, (2) medial rarely (3) rotary (on its long axis), or (4) vertical (rotated on its transverse axis) (Conwell) Manual manipulation with or without anesthesia and with the knee extended will usually replace the bone Hemarthrosis must be relieved and the joint fixed in extension for about three weeks with subsequent treatment as for a sprain

Closed reduction is rarely unsuccessful When it is a vertical incision must be made at the side of the patella and direct traction and leverage used to force the bone over the obstructing condyle into place After care is the same as for the closed treatment

Recurrent dislocation follows insufficient protection after acute dislocation especially when knock knee exists If the valgus is severe appropriate treatment for this is necessary [See Genu Valgum, Chapter 5 — Ed] The simplest and most effective direct attack on the recurrent dislocation is the procedure described by Campbell as follows

A five inch medial incision is made parallel to the quadriceps muscle, the patella and

patellar tendon, down to the capsule of the knee joint. Beginning at a level with the articular surface of the tibia, a strip of capsule five inches in length and one-half to one inch in width is removed and left attached above. In all operations for recurrent dislocation of the patella, the joint should be exposed sufficiently for thorough inspection, in order that any loose bodies not visible in the roentgenogram may be found. After inspection, a digital examination should be made, if necessary.

The cut margins of the capsule are closed, thus taking up all undue slack and tightening the internal portion of the capsule, the pedicled flap being left free. A scalpel is passed from side to side through the quadriceps tendon, just above the patella. Through this *tunnel a hemostat is inserted from without* inward and the end of the flap is grasped and carried through the tendon to the outer side. The flap is then reflected medially over the anterior surface of the quadriceps tendon and the free end is stitched to the internal capsule over the inner condyle, to the proximal end of the internal lateral ligament of the knee or to the internal condyle.

A light plaster or restricting pressure dressing is applied for about two weeks, after which active motion in bed is begun. Ambulatory treatment with crutches is started at the end of three weeks, guarding against sudden, uncontrolled flexion. By the end of six weeks the patient should be walking well without crutches.

Cases with a long, lax, quadriceps mechanism in which the patella lies abnormally high respond well to medial and *distal* transplantation of part or preferably all of the insertion of the tendon. The best example of this type of operation is that of Hauser.* An incision is made from about 2 inches above the patella, curving laterally about the bone and coming to the midline just below the insertion of the tendon. By dissecting up both flaps, the tendon, patella, and lower portion of the quadriceps are exposed. The patellar tendon is dissected free and its insertion outlined. A rectangular block of bone, including the insertion, is cut out to free the tendon. While traction is exerted distally and medially on the tendon, the incision on its lateral side is extended upward through the fascia, lateral to the patella and vastus lateralis. This incision extends down to but does not involve the joint. As the lateral side of the extensor apparatus is freed, the tendon may be moved distally and medially and the proper line of quadriceps action restored. With the patella held by traction in its normal place, between the condyles, a spot is selected for the new insertion medial and distal to the old one. Flaps of periosteum are dissected up and a block of bone the same size and shape as the first block is removed. The first block, with its tendon attachment, is inserted into this space and fixed with a stainless-steel or vitallium screw, or with 4 or 5 C silk sutures in the periosteal flaps. The free block is inserted into the defect at the original attachments. The now-relaxed medial fascia is plicated to make it taut. The gap in the lateral fascia need not be closed The wound is closed with fine silk and plaster is applied in extension for two weeks. If metal fixation has been used, active motion may be started at this time. Otherwise, it should be deferred for four weeks. Protected weight-bearing is permitted at four weeks and free use at six weeks.

Operations to transplant the quadriceps insertion have largely replaced osteotomy of the lateral condyle and building it up with a bone graft in an attempt to block lateral movement of the patella, as advocated by Albee and others. If the correct line of pull of the quadriceps apparatus has been established, recurrence is unlikely.

Dislocation of Tibia from Femur

This rare injury usually follows severe direct violence and may displace the tibia in relation to the femur, (1) anteriorly, (2) posteriorly, (3) laterally, or (4) medially. Rotary displacement may occur alone or in combination with any of the others. Severe

* Hauser, E. D. W.: Total tendon transplant for slipping patella, Figs. 4 and 5, Surg., Gynec., and Obstet., 66:205.

injury to blood and nerve supply may be present and require amputation or other direct surgical attack For this reason, careful examination of the pulses and nerve supply is imperative both before and after reduction Compound dislocation is not infrequent and is handled in accordance with the same principles as outlined above for compound fracture of the patella

Closed reduction is usually easy, since the ligaments are necessarily almost completely torn Traction, combined with appropriate pressure on the head of the tibia, usually suffices Occasionally, the hamstring tendons may be caught in the intercondyloid notch and prevent reduction by traction with the knee extended (Bohler) In such cases, flexion of the knee will usually release the interposed structures

On rare occasions open operation is required, especially in old cases In such instances, a generous vertical incision is made on the appropriate side of the patella into the joint With strong traction applied, preferably by mechanical means, a long bone skid is insinuated between the bones Leverage and manipulation, aided by traction, will bring the bones into proper relationship The wound is closed in layers with interrupted silk

After reduction by either open or closed means, fixation is necessary to allow the almost completely torn ligaments to heal This is best obtained by a circular plaster with perineal weight bearing pad as described for fractures of a tibial or femoral condyle During the application of the plaster, particular attention must be given to proper alignment of the knee, since the disrupted ligaments may allow displacement in almost any direction The knee is best placed in 10 to 20° of flexion Weight-bearing on the walking heel may be allowed in three weeks The circular plaster, however, must remain for from 8 to 12 weeks, according to the severity of the ligamentous injury.

If the knee is not stable at this time, immobilization for a longer period is advised It often does little good When the plaster is removed, crutches and a knee support are used at first and motion is gradually started Function should be complete by the end of six months If the knee is still unstable after adequate immobilization, appropriate operative repair is carried out on whichever ligaments are ununited In cases which are reduced early and in which immobilization has been sufficient the end-result is usually good, and full work in the average case is possible after six months

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38

Internal Derangements of Knee Joint

FRANK E. STINCHFIELD, M.D.

Although the strenuous athletics so popular in recent years and the large number of automobile accidents have added greatly to the involved conditions for which the knee has to be treated, internal derangements of the knee are by no means new surgical problems. It is definitely known that Hippocrates knew of such conditions, although they were first described under the name "internal derangements" by William Hey in 1784. Paré is credited with being the first who successfully removed a loose body from the knee joint and Thomas Annandale of Edinburgh as the first who successfully removed a meniscus.

As surgical technic and asepsis improved, the knee joint became of more and more interest and many methods of treatment were attempted with varying results. The First World War gave great impetus to knee-joint surgery, with the result that during the interim between that war and World War II hitherto unknown surgical procedures have been carried out with safety.

An internal derangement of the knee as defined by Osgood is "a mechanical derangement caused by a product of the joint itself and lying within the joint." The existing pathology may be caused by either a sudden injury or a gradual degeneration of the tissues, or a combination of both.

One of the chief difficulties with which a surgeon is confronted when dealing with disabilities of the knee joint is making the correct diagnosis of the existing pathology. This is in part due to the multiplicity of conditions which can be present. The signs and symptoms of the various pathologic entities of the knee joint resemble each other so closely that only by the most careful investigation can a definite clinical differentiation be made. However, an almost pathognomonic sign of all acute internal derangements of the knee joint is rapid atrophy and hypotonia of the quadriceps femoris.

In examining the joint, one must consider not only the bones, cartilages, ligaments, and synovial membranes, but also the presence or absence of muscular wasting or deformity An evaluation of the range of motion and a comparison with the opposite knee will frequently aid in diagnosis. Anterior-posterior and lateral x-rays should always be obtained before a final opinion is reached.

The most common conditions classified as internal derangements of the knee include the following: (1) Lesions of the internal and external menisci, (2) ruptures of the internal and external lateral ligaments, (3) ruptures of the crucial ligaments, (4) hypertrophy of the alar fat pad, (5) fractures of the tibial spine, and (6) loose bodies in the knee joint. Many others, such as intra-articular exostoses and spurs, ununited fractures of the patella, nonunion of fractures of the tibial tuberosity, foreign bodies (needles, glass, bullets, etc.) in the knee, and peri-articular ganglia, are all de-

rangements of the knee but will not be discussed in this section

Before going into detail regarding specific parts of the knee it may be well to recall a few general anatomic relationships of this joint The capsule a fibrous tissue which completely encircles the joint is reenforced in its posterior portion by the ligament of Winslow The anterior portion of the knee joint is supported by the patella the strong quadriceps muscle group and the patellar tendon The menisci the lateral and crucial ligaments the alar fat pad and the tibial spines will be discussed in connection with their various lesions

MENISCI OR SEMILUNAR CARTILAGES

Anatomy

The menisci are so arranged that they slide centrally and backward when the joint is flexed and peripherally and forward when the joint is extended thus helping the joint stability and allowing the articulating surfaces to keep contact at all times They are attached to the synovial membrane and tibial condyles by tissue known as the coronary ligaments

Functions

The functions of the menisci are many and together with the ligaments they form the stabilizing factors in the knee [The conception that the stability of the *functioning knee joint* is dependent upon normal ligaments and normal menisci is to say the least, debatable It is probably much more accurate to regard the ligaments as check reins designed to prevent excursion of the joint surfaces beyond normal limits Within normal limits of range of motion the joint is stabilized almost altogether by the coordinated action of the muscles which act on it With intact ligaments rotation abduction and adduction of the tibia on the femur are possible in every position except in the maximum of extension and in extreme flexion These two positions are rarely assumed

In any intermediate position the control of rotation abduction and adduction must depend upon the coordinated action of the supporting muscles It is a fact that the removal of both menisci gives rise to no demonstrable instability Were all the muscles uniformly weakened following knee joint injury weakness of the extremity would result but not instability of the joint It is a fact however that the at present unexplained rapid atrophy and hypotonia in the thigh after injury is selective for the quadriceps extensor group and results in marked muscle imbalance hence instability It is for this reason that so much stress must be laid upon the necessity for *quadriceps* rehabilitation in knee joint cases as the author points out throughout this chapter This is not a matter of academic interest—it is a viewpoint vital to understanding of the gross physiology of the living and functioning knee joint and therefore to intelligent understanding of the distinction between the surgical treatment and the operative treatment of that joint Ed]

A few examples of their functions are as follows (1) They compensate for inequalities of the joint surface (2) they diminish friction (3) they adapt themselves to joint motions (4) they assist the lateral ligament of the opposite side of the knee joint to resist any undue lateral motion (5) they act as shock absorbers and (6) they help in allowing rotation of the tibia on the femur

Lesions

By far the most frequent pathology in so called internal derangements of the knee is a fracture or tear of the internal meniscus About 80 per cent of all internal derangements of the knee have this condition as the chief cause of trouble

The signs and symptoms of *a tear of the* internal meniscus are limitation of motion as compared to the opposite side atrophy

and hypotonia of the quadriceps muscle, usually effusion of blood into the joint, and tenderness along the inner joint line—the maximum usually being at the point of tear. Frequently the patient cannot obtain complete extension because of locking of the knee joint. A fairly pathognomonic test is to have the patient sit in a chair and rest his foot firmly on the floor with his knee flexed to 90°, and, with one hand steadying the thigh, to suddenly externally rotate the lower limb on the femur. In so doing, acute pain will be referred to the area of tear. For external meniscus injuries, internal rotation is used. [In the acute cases this test is not so valuable as in the recurrent and chronic cases. In these latter it has been used on the Fracture Service of the Presbyterian Hospital in New York for some years, and has been found very helpful One hand of the examiner must press down on the superior aspect of the lower thigh to hold the foot firmly on the ground, and to prevent abduction or adduction at the hip. If the right knee is being tested the examiner sits in front of the patient, places the left heel in contact with the outer side of the patient's right heel, and the right toe of his shoe in contact with the toe of the patient's shoe. The patient's toe is then suddenly turned outward. Internal meniscus injury, in the great majority of cases, will be evidenced by sharp pain on the inner side of the joint, strictly localized, usually just in front of the internal collateral ligament.

To test the external cartilage, the heel of the examiner's right foot is in contact with the inner side of the patient's heel, and the toe of his left foot turns the patient's toe sharply inward. Similar localized pain is evidenced on the outer side in this case. The turning of the toe must be sharply done, and the patient must be relaxed. If he expects the maneuver, and braces himself in anticipation of it, the test is valueless. Diffuse and nonlocalized pain or discomfort is produced by this maneuver, of course, in any inflammatory or degenerative joint lesion. In acute cases it does not serve to differentiate between meniscus injuries and collateral-ligament injuries.—Ed.]

Anterior tears of the meniscus usually limit extension while posterior tears limit flexion. The history of locking occurs in about 75 per cent of the cases and usually the unlocking of a torn meniscus is rather sudden, produced either by the patient himself or the surgeon. Any slow unlocking should raise doubt as to whether or not there has actually been a meniscus tear. [See below for technic of "unlocking."—Ed.]

Lesions of the external meniscus occur in the frequency of about one to eight or one to ten as compared to lesions of the internal meniscus, due to the fact that the mechanisms producing tears of the internal meniscus are more common than those causing lesions of the external meniscus, and more severe injury is required to damage the external meniscus. Simultaneous injury to both menisci is more frequent than is commonly believed. A much greater variety of pathologic conditions may exist in the external meniscus than in the internal. There may be traumatic tear, hypertrophy, or cyst. Cysts are rather common in the external meniscus but uncommon in the internal. The treatment of an external meniscus tear, hypertrophy, or cyst is exactly the same as if it were in the medial cartilage with the exception that the incision is made in a different location.

A condition peculiar to the external meniscus is that of a discoid cartilage. This condition is the existence of a complete fibrocartilage in the knee joint which represents a persistence of the embryonic structure. Symptoms of such cases may be those of an internal derangement of the knee with locking, pain, disability, and very frequently a "popping" sound when the knee is brought into full extension. McMurray makes a very definite differentiation of distinguishing a "click" which one hears and feels with a tear of the medial meniscus as

compared to a clunk or thud of the lateral meniscus which exists in the discoid cartilage As in cysts of the external cartilages the treatment indicated is operative removal

Conservative Treatment

Almost every case of torn cartilage deserves an attempt at conservative treatment following the first episode This of course is applicable only to those patients in whom a complete reduction of the torn meniscus can be effected It is felt that after two or more attacks operative intervention is warranted

The first step in the conservative treatment is aspiration of the joint and when correctly carried out implies the same careful rigid surgical asepsis as in an open operation The knee is shaved the area about the knee is scrubbed with soap and water for ten minutes and then a surgical preparation with ether iodine and alcohol may be applied (The author prefers nothing but a ten minute scrub with soap and water without application of any other antiseptics)

Aspiration of Knee Joint [See also Chapter 37 — Ed] Usually the aspiration is done using ½ of 1 per cent novocaine anesthesia rather than general anesthesia The most satisfactory site for aspiration is a point midway between the superior and inferior poles of the patella at the level of the cartilaginous surface The needle may be inserted on either the medial or the lateral aspect of the patella In this manner one can be sure that the needle will enter directly into the knee joint and not be displaced into the suprapatellar pouch or into a blind pouch of the knee joint

At the site chosen for the insertion of the needle a small bleb in the skin can be made with ½ of 1 per cent novocaine After this a small nick is made in the bleb with a sharp scalpel to prevent the thrusting of the large bore needle used for aspiration through unpenetrated skin In so doing the possibility of infection is lessened as no outer skin is pushed into the knee joint by a large bore needle The needle used for the novocaine injection is discarded and a large No 17 needle is inserted into the knee joint novocaine being injected as the needle is thrust downward As soon as the needle is through the capsule the hemarthrosis may be aspirated easily

A point of technic that should be kept in mind is that after the needle is in the knee joint an assistant may press the fluid from the suprapatellar pouch down into the knee proper or from the popliteal area up into the knee proper so that as much blood as possible may be aspirated during the one procedure The fluid obtained by aspiration should always be cultured to determine the presence of any bacteria in the knee joint

Oftentimes following this procedure the torn meniscus will spontaneously reduce itself and the knee will go into complete extension or complete flexion A pressure dressing is then applied to the knee for 48 hours after which time the knee is extended to 180° and a circular plaster applied from the groin to the ankle to immobilize the knee This plaster is left in place for a minimum of three weeks and a maximum of six weeks During the time that the patient is encased in this plaster he is given explicit instructions as to the exercising of the quadriceps muscles within the plaster in an effort to diminish or avert as much muscle atrophy as possible and is encouraged to be freely ambulatory bearing weight on the affected leg

[A help in minimizing the tendency of a circular leg plaster to slip down and to produce unpleasant pressure and rubbing just above the malleoli is the preliminary application to either side of the leg of a strip of adhesive extending about six to eight inches beyond the anticipated plaster length After the first layers of plaster are on the exposed lengths of adhesive are turned up and incorporated in the rest of

the encasement. This acts as a suspensory sling to support the plaster and to keep it from slipping down.—Ed.]

If, after aspiration of the knee joint, reduction has not occurred spontaneously, the technics as described by Fisher and Sir Robert Jones are followed. The patient is placed in a supine position with a flexed hip and the lower leg is flexed upon the thigh as much as possible. The lower leg is then abducted upon the femur and suddenly extended while being held in a position of internal rotation. This will usually effect a reduction, provided that the procedure is purely a passive one and the patient's muscles are relaxed In such case, the leg is then placed in a circular plaster as mentioned above, and he is allowed to bear weight immediately. If, after these attempts to reduce a torn internal meniscus, the knee cannot be unlocked, there is but one course that can be followed and that is an open operation with removal of the offending cartilage.

[Many men object to aspiration of a joint shortly before operation. They therefore feel that any manipulation for unlocking should be done on the unaspirated knee joint, the aspiration being done if the joint can be unlocked, and operation advised if it cannot. Also, it is felt by some that there is little excuse for manipulation without anesthesia of a knee joint which is locked. Not only is the manipulation more difficult and less certain of accomplishment, but the presence of flexion due to hamstring spasm in the conscious patient may make it difficult to decide whether or not the procedure has been successful.—Ed]

Should the tear occur completely through cartilage in the mesial portion of the meniscus, there is little hope of it ever healing. Should it involve the periphery where connective-tissue attachment with adequate blood supply is present, the healing is by a fibrous rather than a cartilaginous union. It seems the better judgment that, if conservative methods fail in treatment of a torn cartilage, surgical intervention should be carried out as soon as possible. It is best not to wait too long because of the danger of developing a traumatic arthritis of the involved joint. Therefore, if, after immobilization and muscle re-education and development, the patient still has symptoms referable to the meniscus, operation should be advised.

Operative Treatment

General. Surgical procedures for removal of a meniscus are varied. However, all operative treatment is aimed toward the same end—the removal of the entire meniscus causing the internal derangement. Sir Robert Jones advised that the knee should never be operated on in the presence of an effusion, which advice should be followed as much as possible. Although the fear of opening knee joints has largely disappeared, the danger of infection still exists, and the results of an infected knee joint are tragic. Accordingly, the most rigid asepsis from start to finish should be employed. The greater the respect for the knee joint the better the result.

The patient should be in the hospital for at least 36 hours prior to operation, and should be carefully examined for possible foci of infection that might flare up. Operating on a knee joint in the presence of any systemic infection is injudicious.

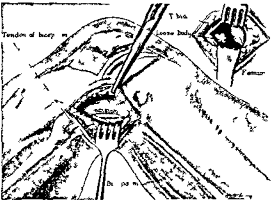
The knee should have two sterile preparations, one on the day preceding operation and one immediately before operation. The leg is made ready with soap, water, alcohol, and ether, and wrapped in sterile towels on two successive days. General anesthesia is recommended. One of the most important parts of the entire operation is the preparation of the field involved. It seems best that the surgeon himself or the first assistant do the preparation of the knee joint. The author believes that the most important part of any preparation is a thorough soap-and-water cleansing which should last for ten minutes. After this, ether and alcohol

can be put on the skin and the field made ready for operation

The use of a tourniquet is of definite advantage at time of operation It will give perfect hemostasis and allow one to see the joint without the hindrance of bleeding Some surgeons feel that the use of a tourniquet predisposes to more muscle atrophy The possibility of a thrombophlebitis and a common peroneal nerve palsy following operation has also been offered in objection to the use of a tourniquet however these have not been substantiated by most clinics

sions and therefore that it is better surgery to explore the joint thoroughly through a large incision He quoted a series of 179 cases in which 27 per cent showed a single lesion 27 per cent showed two lesions and the remaining 46 per cent showed anywhere from three to eleven abnormal conditions in the joint—thus 73 per cent showed multiple lesions

Moorhead has compared the arthrotomy of the knee joint to a laparotomy of the abdomen stating that a small incision for a laparotomy is of no use in the exploration



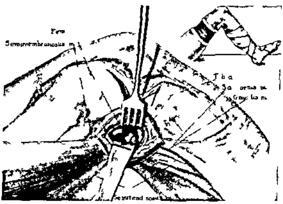


Fig 863 (*Left*) External posterolateral incision Insert shows loose body (Courtesy Henderson M S Surg Gynec and Obstet 33 698)

Fig 864 (*Right*) Internal posterior lateral incision Insert shows knee flexed to right angle and position of leg on operating table (Courtesy Henderson M S Surg Gynec and Obstet 33 698)

[Nevertheless many men prefer operation without tourniquet —Ed]

Whether the skin incision is oblique vertical or transverse is a matter of individual preference However it is wise to avoid injury to the patellar branch of the saphenous nerve There are almost as many types of incisions as there are types of lesions within the knee joint and there still is a great deal of dispute as to whether or not a small or a large exposure of the knee joint should be made Darrach has made an investigation of this problem and concludes that diagnostic ability alone frequently is not sufficient to avoid mistaking the main lesion or in ruling out other associated le-

of the abdominal cavity and likewise a small incision for an arthrotomy is no incision for exploration of a knee

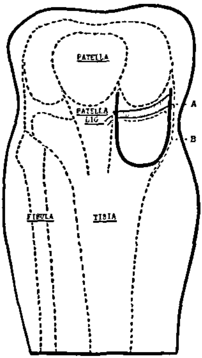
However it would seem that a definite percentage of cases will show sufficient clinical evidence to make one sure that the only pathology is a torn meniscus In these cases it seems justifiable to make a smaller incision as recommended by Henderson Cave Magnuson and others

Types of Incisions As mentioned above there are many types of incisions recommended for approach to the knee joint such as the split patellar the hockey stick the horizontal the posterolateral the U shaped the combined anteroposterior

and the medial or lateral parapatellar. Of these, the most generally accepted as a satisfactory approach is the medial or lateral parapatellar incision: however, a short description of each type is herewith presented.

Split-patellar Incision. Prior to 1920 it was the usual practice of many surgeons to do a split-patellar incision. However, the disadvantage of this is that one chisels through normal bone, and also may have difficulty in placing the cartilaginous portion of the patella in accurate alignment, with the risk that a traumatic arthritis may subsequently develop. Also, there is usually much more postoperative bleeding, and motion cannot be started as early as when one uses the medial or lateral parapatellar incision. The split-patellar incision has been almost completely abandoned in this country at this time and it seems that this has been a wise decision.

"Hockey-stick" Incision. The incision used by Campbell and others passes about one inch to either side of the patella, parallel with the patellar tendon. It begins on a level with the middle of the patella, one inch to its inner or outer side depending on whether the tear is of the internal or external meniscus, and extends directly down to a point just below the articular margin of the tuberosity of the tibia. It is then continued through the soft structures to the joint proper. If more room is required, the lower end of the incision may be carried backward and outward for one or two inches, care being taken not to injure the internal or external lateral ligaments depending on which side the operator is working. Campbell claims that it is usually



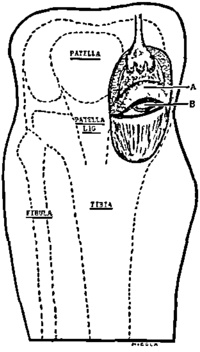


Fig. 865. (*Left*) Line of incision for excision of internal semilunar cartilage: (A) Internal semilunar cartilage, (B) line of incision. (Courtesy, Roberts, P. W.: Jour. Amer. Med. Asso., 79:1608.)

Fig. 866. (*Right*) Flap retracted upward, showing exposure of meniscus on its under surface. (A) Internal semilunar cartilage; (B) medial condyle of femur. (Courtesy, Roberts, P. W.: Jour. Amer. Med. Asso., 79:1608.)

sufficient as the cartilage is often avulsed and can be easily removed

Horizontal Incision Another type of incision is one which is made parallel with the joint line proper and the dissection of the cartilage carried out anteriorly and posteriorly to the lateral ligament

Many surgeons feel and quite correctly

posteriorly may be made in the skin and a straight incision parallel with the longitudinal axis of the leg made in the capsule This may be enlarged and retractors placed to give an excellent view of the posterior cavity of the joint A large curette may be used to explore and to remove the posterior attachment of the meniscus As can be seen

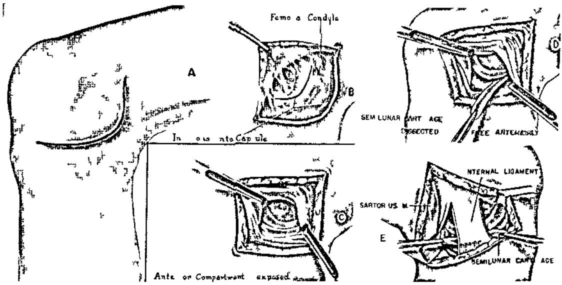


Fig 867 (A) Skin incision beginning about three eighths of an inch back of femoral epicondyle and extending downward and forward to patellar tendon

(B) Incisions into capsule Anterior incision begins just in front of and slightly below femoral epicondyle and extends downward and forward to patellar tendon Posterior incision is made in line with ligamentous fibers of capsule

(C) Anterior opening into joint showing semilunar cartilage in situ

(D) Anterior portion of semilunar cartilage dissected free and brought out through anterior incision

(E) Mesial side of knee joint showing capsule opened in front of and behind internal lateral ligament and cartilage dissected free except for its extreme posterior attachment

(Courtesy Cave E F Jour Bone and Joint Surg 17 428 429)

so that the entire cartilage should be removed if possible Accordingly if a small incision is made anteriorly and the posterior attachment of the cartilage cannot be removed a posterior incision is definitely indicated The posterior incision should be at right angles to the joint line In the case of a torn medial meniscus the knee is flexed to 80°, thus relaxing the posterior capsule

Posterolateral Incision A semilunar incision with the convexity anteriorly or

this approach is anterior to the relaxed tendons of the semitendinosus sartorius and semimembranosus muscles on the medial side (Fig 863) On the lateral side it is directly anterior to the head of the fibula and in front of the biceps tendon (Fig 864) With these two separate incisions almost every cartilage can be removed in its entirety Also the posterior lateral incision which has just been described and was first described by Henderson serves very ade

quately for the removal of any loose bodies from the posterior portion of the knee joint.

U-SHAPED INCISION. Roberts has described an incision for removal of menisci which he believes eliminates the strain on the wound when the knee is flexed and obviates the necessity for suturing the synovial membrane. This is accomplished by making a U-shaped incision, one arm of which starts three-eighths of an inch above the upper border of the tibial condyle and follows down the border of the patellar ligament for one and a half inches It is then carried transversely for a short distance and then upward inside the lateral ligament to the level of the upper end of the opposite arm of the incision (Fig. 865). All tissues overlying the tibia including the periosteum are cut at the same time. A sharp periosteal elevator used to raise the U-shaped flap is retracted upward until the coronary ligament is exposed (Fig. 866) The meniscus then may be removed easily under direct vision.

COMBINED ANTEROPOSTERIOR INCISION. This approach to the knee joint is described by Cave as follows:

> The advantage of the exposure is that it allows exposure to the anterior and posterior compartments of the knee joint with a minimal amount of trauma to the articular surface. The technic is to flex the knee at right angles over the end of the operating table. To expose the internal meniscus, the internal epicondyle of the femur is identified and the incision begun three-eighths of an inch behind and on a level with this point about 1½ inches above the joint line. Posterior to this bony landmark pass the tendons of the sartorius gracilis and inner hamstring muscles, which have their insertion in the upper end of the tibia. The incision is carried downward and curved gradually anteriorly to a point a quarter of an inch below the joint line and then forward to the border of the patellar tendon (Fig. 867 A). The skin flap of subcutaneous tissue and fat is reflected upward to expose the quadriceps expansion and the lateral ligament. The first, or anterior, incision into the joint capsule begins just in front of the lateral ligament as it takes its origin from the internal femoral condyle (Fig. 867 B). The incision is carried downward and forward to just below the joint line and farther forward to the patellar tendon with the same general curve as the skin incision. The synovia is opened through this same incision and the anterior cornu of the internal meniscus is exposed (Fig 867 C) In this manner one can work in front and behind the lateral ligaments which allows adequate exposure to the entire joint (Fig. 867 D). This incision is very adequate for any exposure that is necessary (Fig. 867 E).

PARAPATELLAR, MEDIAL LATERAL, OR PATELLAR-MARGIN INCISION This incision (sometimes called medial lateral or patellar-margin incision) begins in the midline of the thigh about three inches above the superior aspect of the patella, passes downward to within a fingerbreadth of the superior aspect, and then along the inner margin of the patella and patellar ligament to the tibial tubercle. The chief advantage in making such a large incision is that should other lesions be present they may be approached and treated through the same incision.

The surgeon should incise directly to the level of the fascia, the vastus internus should be retracted medially to avoid cutting the muscle fibers. The capsule is opened to the full length of the skin incision The rectus femori tendon is split longitudinally in the direction of its fibers close to its *medial margin for a distance of about two* inches into the suprapatellar pouch. By this maneuver the patella can be displaced or dislocated laterally when it becomes necessary to expose the entire joint. The knee should be flexed at right angles for the best exposure after dislocation of the patella. The removal of the meniscus usually begins at the anterior attached portion and is facilitated by external rotation of the tibia. Attempts should be made to remove the entire meniscus even if it becomes necessary to make a separate incision to expose the posterior portion. One should be careful to avoid injuring the medial lateral

ligament when dissecting off the medial meniscus

Removal of Medial Meniscus As soon as the knee joint is entered, it should be inspected in a systematic manner for possible loose bodies, new growths, synovial hypertrophy, or adhesions The ligamentum mucosum should then be severed In the event that the patellar fat pad obscures complete vision of the knee joint, it should be removed immediately, this being necessary in almost every case before adequate exposure is obtained The crucial ligaments are then inspected for possible tear, although in most cases it is not necessary to repair them if they are torn

The knee is then brought into complete extension and the patella dislocated laterally By this maneuver the lateral compartment of the knee is adequately exposed and the lateral meniscus may be inspected Following this the torn medial meniscus is exposed Its anterior horn is then severed from the anterior transverse ligaments and the severed portion grasped with a heavy Kocher forceps By the use of cartilage scissors or a sharp curved Bard Parker knife, the meniscus is dissected free from the coronary ligaments binding it to the tibia As soon as it may be prolapsed or pulled into the intercondylar notch it is advisable to do so In this way the posterior attachment can frequently be exposed from the anterior approach and severed by using a long knife or scissors Sometimes a tonsil snare instrument will help cut the posterior attachment Although many surgeons feel that it is not absolutely essential to remove the posterior third of the meniscus it is generally felt to be a much safer procedure If it is impossible to remove the entire meniscus through the anterior approach, the separate posterolateral incision of Henderson may be made In this way the posterior third of the cartilage may be dissected free and removed without difficulty

After removal of the medial meniscus, should a tear of the lateral meniscus be present the entire lateral meniscus should be removed in the same manner as the medial Any areas of osteochondritis of the femoral or tibial condyles or the articular surface of the patella should then be removed, being shaved through by small strokes of a very sharp and thin osteotome or scalpel

After complete exploration of the joint, the patella should be replaced and the knee joint irrigated with 400 to 500 cc of normal saline By doing this and moving the knee joint at the same time any free or loose pieces of cartilage may be floated to the surface and removed The capsule of the knee joint is then sutured with interrupted fine black silk sutures The two layers of the quadriceps expansion are then sutured independently and also the deep fascia The skin may be closed with either interrupted or continuous lock sutures of black silk Sterile dressings are applied and if a tourniquet has been used pressure dressings should then be applied from the ankle to the groin

This is done by applying a moderately thick continuous wrapping of one inch cotton batting from the toes to the groin Over this is applied a continuous Ace bandage which exerts moderate pressure on the entire leg Following this a similar layer of cotton batting and Ace bandage is superimposed upon the first one and wrapped in an identical manner except that a little firmer pressure is exerted than with the first wrapping The knee is always held in complete extension when the pressure dressing is being applied The first dressing is left in place 24 hours and the second for 36, thus effecting immobilization and hemostasis for the immediate postoperative period If a tourniquet is not used, the necessity for the pressure dressing is not as great, and it may be dispensed with if the operator wishes

Postoperative Treatment of Torn Menisci Upon the return of the patient to his room the leg should be elevated on at

least two pillows. Immediately upon the patient reacting after the anesthesia, he should be encouraged and instructed to rhythmically contract the quadriceps muscles of the affected leg at frequent intervals. The earlier the return of quadriceps function, the less the muscle atrophy and the shorter the disability time. He should also be encouraged to attempt to lift his heel off the bed as soon as possible, as this is another way of obtaining early return of quadriceps power. After the initial discomfort and pain have subsided, which is usually within the first 36 to 48 hours, the patient should be encouraged to flex and extend his knee within pain limits. It is extremely important that the patient keep the knee in complete extension when not moving it, in order to prevent contracture of the hamstring muscles, as this produces an improper weight-bearing line and predisposes to unnecessary joint trauma when beginning walking.

If there are no contraindications or complications, the patient is allowed in a wheel chair on the fourth day. Walking is instituted on the seventh day. It is advisable to teach the patient to walk correctly without the aid of cane or crutches. He should be instructed to stand erect with head and eyes up, shoulders back, hips and pelvis held forward, and knees straight. He should be taught to walk with small even steps, bearing full weight on the affected leg. Crutches *may be permitted for a day or two, but no* longer than absolutely necessary; otherwise the patient will become dependent on them.

Unless there is some good reason to do otherwise, it is best not to dress the wound for at least a week following operation. The sutures are usually removed on the seventh, eighth, or ninth postoperative day.

As mentioned above, the patient should be on quadriceps muscle exercises from the day of operation until complete return of muscle power and size. This frequently takes several months. Exercising the knee over the end of the table, faradic electrical stimulation, squatting exercises, riding a stationary bicycle, and short running exercises all help to develop the quadriceps.

The patient usually may be discharged from the hospital on the eighth to tenth postoperative day, and should be seen weekly for the next six weeks. This is chiefly to prevent the development of bad habits in walking and to be sure that the muscle exercises are being carried out adequately.

The average time of return to work after operation varies according to the patient and his occupation. Many clerical workers may start work 10 days to two weeks postoperative. A patient who does heavy work may be laid up for three to four months.

LATERAL LIGAMENTS

Anatomy and Functions

The function of the lateral ligaments is to prevent lateral instability of the knee joint. The internal lateral ligament prevents abduction of the lower leg on the upper leg when the knee is in complete extension, and the external lateral ligaments prevents adduction of the lower leg upon the upper leg when in complete extension. The internal and external lateral ligaments, both menisci, and both cruciates are taut in complete extension. However, only the anterior portion of the internal lateral ligament, both menisci, and both cruciates are taut in flexion *while the external lateral ligament remains* relaxed. [See comments on stability of the knee joint, p. 1052.—Ed.]

The internal lateral ligament lies on the internal aspect of the knee joint and measures about one and a quarter to two inches in width, being composed of an anterior and a posterior portion. The anterior portion of this ligament is by far the most important, and is constantly taut in both flexion and extension. The posterior portion is relaxed in flexion. From a surgical standpoint this is of extreme importance, because it is necessary to reconstruct only the anterior por-

tion in tears of the medial lateral ligament

At its upper end, the internal lateral ligament is attached just below the adductor tubercle and at its lower end to the upper margin of the medial tibial condyle This ligament however, is intimately attached to the internal meniscus and to the capsule of the knee joint

The external lateral ligament is a fibrous, rope like structure about the size of a lead pencil attached to the femoral condyle at its upper end and to the head of the fibula at its lower end This ligament lies posterior to the midline of joint and is separated from the lateral meniscus by the popliteus tendon and a small bursa

The internal lateral ligament is of much greater importance than is the external because there is a marked increase of rotation of the lower leg in flexion when it is cut One can understand why some surgeons occasionally feel that it is necessary to repair only the internal lateral ligament but do not worry about tears of the external lateral ligament

Lesions of Internal Lateral Ligament

Lesions of the internal lateral ligament are much more common than those of the external lateral ligament The long anterior portion of the ligament may suffer damage at either upper or lower attachment or both The etiology, the signs, and the symptoms of tears of the internal or external lateral ligaments are frequently similar to those of tears of the menisci, except that the symptoms are not quite so severe The patient usually gives a history of a severe torsion or forced abduction of the leg on the thigh with excruciating pain on the inner aspect of the knee There is usually no history of locking Hemarthrosis may occur in the severe cases, and, if so, it usually appears immediately, since the internal lateral ligament is intimately attached to the medial cartilage A tear of the internal lateral ligament is at times accompanied by a lesion of the internal meniscus Examination usually shows tenderness at the lower end of the attachment of the ligament The lower leg may be abducted on the thigh in full extension which is normally not possible In chronic cases, the lateral mobility is increased somewhat if there has been repeated trauma to the involved ligament Pain is usually over the attachment of the ligament and sometimes a bony thickening from ossifying periostitis can be detected Wasting of the quadriceps and evidence of a chronic synovitis are usually a part of the picture

Conservative Treatment In early tears of the internal lateral ligament conservative therapy is usually sufficient The main objective should be functional rather than anatomic restitution of the affected joint

Fisher recommends that the following method of treatment for the original injury be followed Firm elastic pressure should be applied to the joint at the earliest possible moment This not only prevents further extravasation of blood or synovial effusion but also assists the absorption of any which may have already occurred As soon as the effusion has appreciably subsided and this is usually after the third or fourth day he advises massage and gentle active motion These usually relieve pain and are welcomed by the patient When the effusion has entirely subsided, weight bearing may be commenced During the reparative stage he recommends that the stress be relieved by shifting the body weight to the outer side of the foot

However, it is felt by the author that the rupture of the fibers of the internal lateral ligament are apt to give a persistent laxity of this ligament and imperil the function of the knee if external protection is not applied, therefore the routine of aspirating the hemarthrosis under aseptic precautions and immobilization in a circular plaster is recommended Weight bearing is commenced within three or four days to maintain the tone of the quadriceps It might be said that more attention is paid to the constant exer-

cising of the quadriceps within the plaster than to the actual treatment of the tear of the ligament as it is felt that the development of these muscles is much more important in obtaining a good knee than is the immobilization. However, we do not feel that the tendon can heal satisfactorily without immobilization; therefore, the plaster is worn for six to eight weeks. An orthopedic heel with one-quarter to three-eighths of an inch lift may be put on the inner aspect of the shoe to shift the body weight to the outside of the foot, and throw the foot into varus position.

Operative Treatment. Frequently, conservative treatment of torn internal lateral ligaments is not satisfactory and it is necessary to resort to operative treatment. For such cases many ingenious operations have been suggested, although it must be recognized that complete restoration to normal is hardly ever possible. All operations aim at accurate substitution of a new internal lateral ligament directly over the torn anterior portion of the old ligament. [There are two criteria for operative interference in collateral ligament tears: (1) The presence, after conservative therapy, of more than 10° of passive instability in complete extension, and (2) symptoms of clinical instability *in the presence of good quadriceps tone and power*. Clinical instability in the presence of atrophy and hypotonia of the quadriceps should be given a thorough trial of quadriceps rehabilitation, with a temporary knee cage for stabilizing purposes, before subjecting the patient to operation. See comments on stability of the knee joint on p. 1052 of this chapter.—Ed.]

The following are some of the accepted procedures for repair of a torn internal lateral ligament.

EDWARDS' METHOD. The tendons of the gracilis and semitendinosus are exposed and severed at the level of the medial condyle of the femur. The distal portions are pulled well forward after having been sutured firmly together and inserted into a groove previously made in the inner femoral condyle, in the line of the internal lateral ligament. After fixation in this position by a staple, the fibrous tissues of the condyle are then sutured over the tendons as they lie in the groove. The proximal ends of the tendons are sutured to the sartorius. In this manner the internal lateral ligament is again established.

COTTON AND MORRISON'S METHOD. There is usually a tear of the internal lateral ligament accompanying tears of the anterior crucial ligament. The above authors are of the belief that repair of the lateral ligaments is much more effective than an attempt to repair the crucial ligaments, because the crucials are so difficult to repair and the results so unsatisfactory. Consequently, they have devised a scheme known as the X-suture for repair of the internal lateral ligament, the technic of which is as follows.

A strip of fascia lata is used as the X-suture To avoid interference with motion, the newly formed ligament must be attached near the radial center of the curve of the femoral joint surface if an internal lateral ligament is being made, and not too far backward or forward at the tibial attachment. To get strong mooring, the fascial strip must go deep under a strong bridge of cancellous bone. That means two holes, and, in order to avoid an undesirable broad ribbon of ligaments, it means an X-crossing of the false ligaments. The fascia is drawn taut, knotted, and the knot fastened with gut or fine silk sutures. The whole operation, even if both inner and outer sides are operated upon, can be done without opening the knee joint. According to Cotton and Morrison, motion in three weeks and weight-bearing at six weeks is followed by excellent results.

CARRELL'S METHOD. Carrell feels that most of the ligaments of the knee joint can be treated conservatively. However, he admits that there are some cases in which extensive laceration and poor management

make it necessary to repair the internal lateral ligament He has described the following operation which he uses in these instances

A strip of fascia from the iliotibial band is reflected downward to a point just above the lateral condyle The strip is two inches wide by eight inches long The medial side of the knee is then exposed, and through a stab wound in the deeper tissues a guide is passed directly behind the femur just above the condyles to emerge on the lateral side through the vastus lateralis The fascia is pulled through along the guide and on the medial side is reflected forward to the center of the condyle It is then pulled directly downward to the medial side of the tibia On the surface of the femoral condyle where the fascia is in contact, a channel is made by introducing a broad osteotome and lifting backward a layer of bone and fascia permitting the fascial strip to come in direct contact with the freshened bone Two drill holes are placed an inch apart on the medial side of the tibial tuberosity The fascia is split and each half passes through one hole and emerges at the other The ends are secured under tension with silk ligatures The incisions are closed and the leg is put up in a straight position with plaster from toes to groin A walking boot is attached and the plaster is worn for eight weeks Gradual resumption of function with quadriceps exercises is followed for another 40 or 60 days

CAMPBELL S METHOD A skin incision is made on the anteromedial aspect of the knee parallel with the quadriceps tendon, the patella, and the patellar tendon beginning two or three inches above the patella and extending just below the tibial tubercle (Fig 868 A) The anterior flap of the skin incision is dissected up and a small incision is made into the knee joint The joint is carefully inspected and the cartilages removed if internal derangement exists

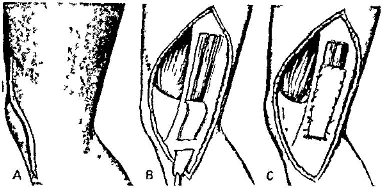


FIG 868 (A) Internal incision parallel to patellar tendon which gives access to joint and internal ligament (B) Dissection of flap which is passed through a tunnel in soft tissues over internal condyle of tibia, one inch distal to joint (C) Flap drawn taut through tunnel and stitched in place (Courtesy, Campbell, W C Amer Jour Surg, 43 474)

To repair the ligament, a strip of deep fascia one half an inch wide and four inches long is dissected from the inner aspect of the knee from above downward to a point opposite the center of the internal condyle of the femur An incision one inch in length is then made through the lower portion of the deep fascia and periosteum down to the bone one inch below the upper extremity of the tibia, parallel with the line of the joint Parallel to this incision and one inch lower, over the tibia, an incision of equal

length is made. A hemostat is passed through the lower incision close to the bone and brought out through the upper incision. The free end of the fascial flap is grasped with the hemostat and drawn through the tunnel in the dense fascia and periosteum (Fig. 868 B). With the knee at 150° extension and the leg forcefully adducted on the thigh, the fascial flap is drawn tight and sutured as high as possible to the margin of the fascia from which it has been dissected (Fig. 868 C). This provides an adequate pulley action and re-establishes a tight internal lateral ligament.

If the tissues on the medial condyle of the tibia are not sufficiently strong to withstand considerable tension, a strip of fascia lata may be passed through a tunnel in the bone and sutured to itself. In cases where the fascia on the inner aspect of the thigh is not well developed and not sufficiently strong for this procedure, another procedure such as Mauck's or Edwards' operation may be done. Postoperative treatment includes immobilization from four to six weeks in a circular plaster, and then beginning graduated easy motions.

Mauck's Method. Mauck feels that the problem consists of finding some operative procedure which would accurately and effectively shorten the relaxed ligaments and eliminate that weakened part which is made up of scar tissue. In addition to this, some provision should be made to allow early use for restoration of the weakened and atrophied muscles. Mauck has described the following technic for the repair of the internal lateral ligament.

A slightly curved anterior incision is made over the inner aspect of the joint extending from the adductor tubercle of the femur to four inches below the articular surface of the tibia (Fig. 869 A). This is carried through the skin and fascia, which are dissected backward and forward, so that the structures can be retracted and the whole of the inner side of the capsule and of the head of the tibia can be exposed.

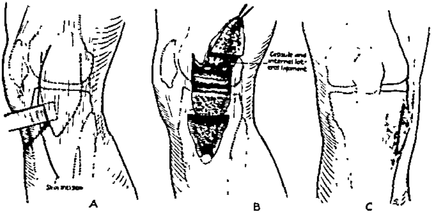


Fig. 869 Mauck's operation for repair of torn and relaxed internal lateral ligaments. After elevation of internal lateral ligament with its bony attachment, fascial bone flap is drawn distally as far as possible and anchored beneath a groove in internal condyle of tibia. (Courtesy, Campbell, W. C.: Amer. Jour. Surg., 43:475)

With a broad chisel, the inner side of the head of the tibia with the lateral ligament attached is removed and reflected upward. This section of bone is from one and a half inches to two inches in length and about one-half an inch thick at the articular surface and triangular in shape. At the joint surface, the capsule is split upward for about an inch at both the anterior and posterior margins of the bone flap. As the

flap of the capsule with the bone attached is reflected the internal meniscus will be seen to be attached to the flap but still bound to the head of the tibia at its anterior and posterior ends (Fig 869 B) After full reflection the cartilage is removed with a scissors from its attachment to the inner aspect of the flap To shorten the ligament the ligament and bone flap are drawn strongly downward and the point to which the articular surface of the bone flap can be brought is marked by a chisel cut This distance averages three quarters of an inch The maximum is one and a quarter inches One quarter of an inch below this point a notch is chiseled into the side of the tibia according to the depth and width of the bone flap Additional bone is then removed from below to accommodate the flap At the lower end a small shelf of overhanging bone is left under which the lower end of the transplanted bone flap can be slipped and locked The upper margin of the area of the tibial end is beveled upward and inward and the upper articular surface of the bone flap is denuded of cartilage by beveling downward and outward The bone flap is then mortised into the new bed and locked by slipping the lower end of the flap which has been slightly shortened under the overhanging shelf of the bone (Fig 869 C) It should be noted that the part of the ligament formed by scar tissue is brought against the denuded bone of the tibial head above the new bed The inner surface of this part of the capsule should be scarified so that in healing it will be firmly adherent to the bone and entirely eliminated from the shortened ligament The whole bone flap can be implanted forward on the new bed if one wishes to increase the obliquity of the anterior fibers of the ligament which might act as an additional check on any forward movement of the tibial head on the femur This has not been necessary in most of the cases After closure of the wound a hinged plaster is applied The knee is kept quiet for two weeks The patient is then allowed to be up with the use of the leg in graduated exercises for development of the quadriceps Use of the hinged plaster is advocated for six weeks

Lesions of External Lateral Ligament

Injuries of the external lateral ligament are usually produced by violent adduction with the knee extended Pain and tenderness are usually present over the lower attachments of the ligament Effusion into the joint rarely occurs The conservative treatment of this lesion is identical with the conservative treatment of the internal lateral ligament tear except that the outer rather than the inner portion of the heel should be raised so as to throw the foot into valgus position and thus relieve the strain on the lateral ligament However in cases with marked instability it is necessary to do a reconstruction operation

Operative Treatment Edwards has devised an operation for repair of a torn external lateral ligament in which he transplants a portion of the biceps tendon to the lateral femoral condyle and then reinforces this with a strip of the iliotibial band

Campbell Cotton Morrison and Carrell s methods are all applicable to the repair of the external lateral ligament as well as the internal It must be remembered that the important part of reconstruction of the lateral ligament is not the actual tendinous reconstruction but rather the muscular supporting mechanism about the knee joint In other words the stabilizing structures must be developed to a very high degree to give adequate and complete support to the knee joint In conjunction with this a repair of the lateral ligament may be of advantage but without the muscular power the repair of the ligament is of very little benefit

The postoperative treatment of torn internal and external lateral ligaments is essentially the same as that used in cases of tears of the menisci

CRUCIAL LIGAMENTS

Anatomy and Functions

The crucial ligaments give stabilization chiefly in the anteroposterior direction. The anterior crucial ligament arises posteriorly from the interior surface of the external condyle of the femur and extends downward, forward, and inward to be inserted at its lower or anterior end to the anterior intercondylar area of the tibia and the adjacent portion of the anterior tibial spine. The posterior crucial ligament arises just forward on the outer surface of the inner femoral condyle and extends outward, backward, and downward, crossing the anterior crucial ligament, and attaches at its lower extremity to the posterior intercondylar area of the tibia.

The functions of the crucial ligaments have been described very well in an article on mechanics of the knee joint by Brantigan and Voshell in the Journal of Bone and Joint Surgery, vol. 23. The function of the anterior crucial ligament is to prevent forward gliding or displacement of the tibia upon the femur beyond normal limits in the flexed position. The posterior crucial ligament prevents posterior displacement of the tibia on the femur beyond normal limits in the flexed position. It is a well-known fact that both crucial ligaments may be cut and the knee will be stable in extension because of the function of the lateral ligaments. The crucial ligaments in themselves prevent internal rotation of the tibia on the femur because in this action the cruciates twist or become taut on each other. However, in external rotation the cruciates have no limiting effect because they have a tendency to untwist upon each other. It also has been shown that the anterior crucial and the internal lateral ligaments lend more support to the knee joint than the posterior crucial or the external lateral ligament. Therefore, it is readily seen that the greatest function of the crucial ligaments is in the restricting of hyperflexion, hyperextension being limited by the lateral ligaments.

Ruptures

One will remember that the same mechanism that causes a tear or fracture of the internal meniscus, if carried through to its end, will usually cause a tear of the anterior crucial and internal lateral ligaments. Sometimes one, or both, or all of these may be injured. Rupture of the external lateral and posterior crucial ligaments, and the external meniscus is rare because the mechanism causing this type of injury is comparatively rare. It will also be remembered that the crucial ligaments prevent anterior and posterior displacement of the tibia on the femur while the lateral ligaments prevent any lateral instability of the lower leg on the upper leg in complete extension. Therefore, any repair must be done with the idea of re-establishing the normal anatomic relationship of the torn ligament.

Although a rupture of the anterior crucial ligament is most commonly produced by violent internal rotation of the femur on the tibia with the knee flexed, it may also be produced by forcible extension. It is possible to have a stretching of the anterior crucial without a complete severance. The characteristic sign is displacement of the tibia forward on the femur when the knee is flexed. The patient complains of instability of the knee but does not have the locking which is characteristic in tears of the menisci. There is an abnormal arc of rotation either of the femur inward or the tibia outward following a tear of this ligament.

The mechanism of a rupture of the posterior crucial ligament is exactly opposite to that producing a tear of the anterior crucial ligament. It is usually produced either by extreme flexion with displacement of the tibia backward or by external rotation of the femur on the tibia. This lesion occurs much less frequently than tears of the anterior crucial. The characteristic sign

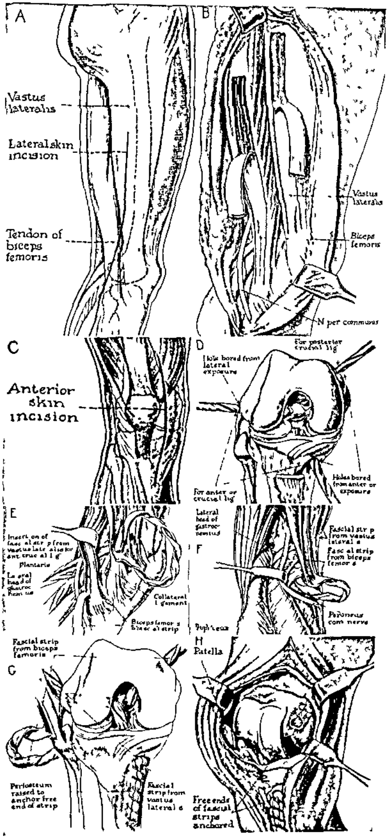


FIG 870

For legend see p. 1069.

is displacement of the tibia backward on the femur when the knee is flexed to right angles. However, the subjective symptoms are identical with those found in tears of the anterior crucial.

Conservative Treatment. The general consensus is that operation for crucial ligament tears is not wholly satisfactory and that the conservative method of prolonged immobilization is the most practicable.

Any existing block to extension must first be reduced. This may be accomplished by closed manipulation, as described under the section on tears of the medial meniscus, or by open operative procedures. After this, the leg should be encased in a circular plaster extending from the groin to the ankle with the knee in complete extension. The knee should be immobilized for a period of five to six weeks during which time exercise of the quadriceps and other muscles must be instituted. After removal of the plaster, the mobility of the joint may be restrained to a certain extent for some weeks by the wearing of a hinged knee cage, and by raising the inner side of the heel and sole of the shoe to relieve strain upon the internal lateral ligament.

Operative Treatment. Many surgical procedures have been advised for repair of the crucial ligaments, but, generally speaking, the results have not been entirely satisfactory. Suturing the crucial ligaments in fresh cases is extremely difficult due to the fact that in the majority of cases the rupture occurs so near the bone that suture is impracticable. Sir Robert Jones and R. Lovett stated:

> The writers have examined several of these cases of ruptures of the crucial ligaments without having seen a perfect result, but several have been much improved. The operation is usually grave and requires highest craftsmanship, and should never be undertaken without a sense of grave responsibility.

Some of the outstanding surgical procedures for repair of the crucial ligaments follow.

CUBBINS' METHOD (BOTH CRUCIAL LIGAMENTS). After a thorough preparation of the involved knee and the use of a tourniquet to give the operator a bloodless field, a posterolateral incision 12 inches long extending from well above the middle of the thigh down to one inch below the head of the fibula is made (Fig. 870 A). The bicipital aponeurosis is dissected off the muscle to the true tendon and about one-third of the true tendon is separated down to the head of the fibula. Then a strip of the posterolateral portion of the vastus lateralis fascia is picked up and dissected down to exactly opposite the lateral condyle (Fig. 870 B). After this step, the knee joint is opened through a median parapatellar incision (Fig. 870 C). A ⅜-inch drill opening

FIG. 870. (A) View of thigh, showing bones and muscles in outline and line of incision. Aponeurosis and tendon of biceps femoris shown in white.

(B) Primary incision, beginning dissection of fascia strip from vastus lateralis and removal of aponeurosis from biceps femoris. Note width of fascial strips and points to which they are to be dissected.

(C) Incision medial to side of patella. Anterior surface of knee joint.

(D) Bones shown in outline. Note points at which drills are inserted from without in.

(E) Fascial strips have been dissected to their lowest points and strip of fascia from vastus lateralis has been slightly twisted and drawn through opening in posterior portion of lateral condyle.

(F) Point at which slightly twisted aponeurosis and tendon of biceps are carried up beneath popliteus and lateral to outer head of gastrocnemius and peroneus communis nerve.

(G) A portion of new anterior cruciate as it passes between condyles, and position where new posterior cruciate is buried in osteoperiosteal bed beneath synovia.

(H) Tendons in outline and their relations in intercondylar notch. Note how terminal portion of new tendon is buried in osteoperiosteal bed.

(Courtesy, Cubbins, Conley, Callahan, and Scuderi: Surg., Gynec., and Obstet., 54:299-305.)

is now made through the medial condyle at its anterior and upper portions above the cartilaginous line obliquely back and down to the upper portion of the intercondylar notch Another drill hole is made in the medial surface of the tibia just in front of the anterior spine The lateral incision is then re opened and a hole is drilled through the posterior portion of the lateral condyle just above the collateral fibular ligament extending transversely into the knee joint entering at the upper posterior portion at the point where the anterior crucial ligament originates (Fig 870 D) The fascial strip from the vastus lateralis which is to form the anterior crucial ligament is drawn through the hole in the lateral condyle just above the collateral fibular ligament (Fig 870 E) The biceps tendon fascia which is to form the posterior crucial ligament is carried laterally to the head of the gastrocnemius and then beneath the tendon of the popliteus to where it is pushed through the posterior ligament of the knee joint (Fig 870 F) The anterior crucial ligament is then threaded downward and forward through the head of the tibia and the posterior crucial is pulled up through the medial condyle (Fig 870 G) The ends of these re formed ligaments are then sutured to the periosteum of the femur and tibia (Fig 870 H) After this procedure the knee joint is closed and the limb is supported at an angle of 25° flexion A circular plaster is applied from the groin to the ankle which is left in place for four weeks At the end of six weeks active motions are allowed No attempts at walking are allowed until the end of 14 weeks A brace is then fitted and worn for another six to eight weeks

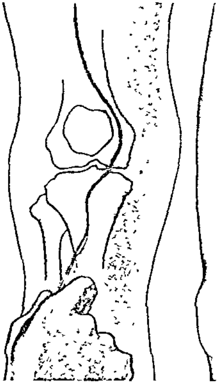
STRICKLER S METHOD (BOTH CRUCIAL LIGAMENTS) A long incision is made over the external surface of the thigh extending from just above the knee joint well up on the thigh to allow for a good long liberal strip of fascia lata The defect in the fascia lata caused by removing this strip is closed with chromic gut No 2 This leaves the fascial strip free at the upper end and still attached near the knee joint The knee joint is then opened by a medial parapatellar incision The muscles above the external condyle of the femur are separated by blunt dissection down to the bone A drill about the size of a lead pencil is passed through the femur from a point above the external condyle of the femur to the middle of the intercondylar notch then with the knee flexed to a right angle and the knee joint open the same drill is passed from a point anterior to the tibial spine in the direction of a point on the tibia just below the capsule of the knee and slightly anterior to the neck and head of the fibula The strip of fascia is passed through the holes in the tibia and femur and is then pulled through the knee joint fairly snugly with the knee joint extended The medial parapatellar incision is then closed The strip of fascia is now passed externally over the joint capsule lateral to the patella and fastened to itself at the point where the fascia entered the femur above the external condyle The knee joint is then closed in layers

To maintain extension of the knee joint a circular plaster from toes to groin is applied and worn for six weeks After this time the patient is fitted with a simple leg brace After eight weeks gradual motion is started in the knee joint with gentle massage Six months after operation the patient should be getting around satisfactorily Strickler claims that this operation works equally well in ruptures of either anterior or posterior crucial ligaments

CAMPBELL S METHOD (ANTERIOR CRUCIAL LIGAMENT) A longitudinal curved incision about six inches in length is made parallel with the quadriceps tendon Dissection is made into the joint and the joint inspected Repair of the anterior crucial is made by dissecting a long pedicle of fascia capsule and tendon from the lateral edge of the incision one third of an inch in diameter and eight inches in length It is dissected

from the above downward to the attachment of the capsule to the tibia. A 6-mm. drill hole is then made from a point on the anterior internal surface of the inner tuberosity of the tibia about one and a half inches below the joint to emerge at the normal attachment of the anterior crucial ligament. The same drill is then inserted into the intercondylar notch and driven through the posterior portion of the external condyle of the femur to emerge under the skin above and posterior to the external condyle. A three-inch incision is then made over the point of the drill with dissection down to the bone at this point. The newly formed pedicle of fascia is now drawn through the already made holes. The fascia is drawn taut with the knee at an angle 140° in flexion. Three inches of the strip extends beyond the external drill hole and the fascia is sutured snugly to the periosteum. Both wounds are now closed and a posterior splint applied with the knee in full extension, which further increases the tension on the new ligament.

The after-treatment consists in fixation by a posterior splint for a period of three weeks when active and passive motion is instituted The author reports excellent results with this method.



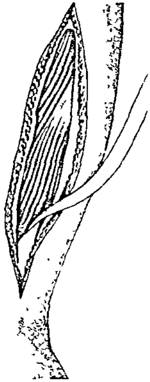


FIG. 871. (*Left*) General utility incision for exploration of knee joint. (Courtesy, Krida, A.: Jour. Bone and Joint Surg., 15:898.)
FIG. 872. (*Right*) A long strip of fascia lata is secured and allowed to remain attached at its lower pole. (Courtesy, Krida, A · Jour. Bone and Joint Surg., 15:899.)

KRIDA'S METHOD (ANTERIOR CRUCIAL LIGAMENT). The technic is based on the Hey-Groves and Alwyn Smith method. A median parapatellar incision is made and the patella is displaced over the external condyle (Fig 871). The operation is done under a tourniquet placed as high on the thigh as possible. After the joint has been

exposed and the pathology determined a separate long incision is made on the outer side of the thigh (Fig 872) A strip of fascia lata at least ten inches long and an inch and a half wide is stripped from above downward leaving the lower attachment intact A cord is made of the strip by rolling its sides together The patella is then displaced and the joint is flexed to a right antero internal face of the tibia (Fig 873) Here it is unrolled pulled quite tight with the joint flexed about 20 and is sutured firmly to the periosteum The remainder of the strip is reflected upward on the internal condyle of the femur The bone is bared and the synovia is sutured over the strip (Fig 874) In this way the anterior crucial ligament has been re established and the in

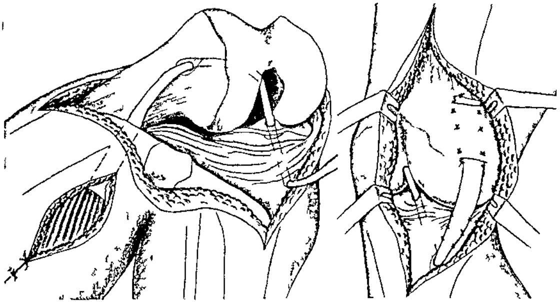


Fig 873 (*Left*) Course of fascial strip through bone tunnels of knee joint (Courtesy Krida A Jour Bone and Joint Surg 15 900)
Fig 874 (*Right*) End of fascial strip is used to reconstruct lateral ligament (Courtesy Krida A Jour Bone and Jo nt Surg 15 900)

angle A quarter inch drill hole is made through the external condyle in a direction from above downward terminating posteriorly in the intercondylar notch A second drill hole is made through the internal tuberosity of the tibia from within outward terminating at the anterior insertion of the anterior crucial ligament The lower portion of the long incision is then again exposed An opening is made through the vastus externus into the joint The fascial strip is then pulled through The strip is then pulled successively through the femoral and tibial drill holes terminating on the ternal lateral ligament has been re enforced

The knee is immobilized for three weeks in 20° flexion Physical therapy measures are then directed to the development of the quadriceps walking at first with support then with no brace No passive motion is used but the patient regains his motion and use by voluntary exercise

Carrell s Method (Anterior Crucial) The entire lower extremity is prepared and before application of the tourniquet the strip of fascia is reflected from the outside of the thigh The incision extends from the lateral condyle along the outside side of the

thigh for a distance sufficient to reflect a strip of fascia eight inches in length and two inches in width downward to the condyle. The base of the strip remains attached at the lower end.

Through a medial parapatellar incision the joint is inspected and any additional surgical procedure that may be necessary is carried out. The lateral incision is again exposed and a deeper incision is made through the vastus lateralis to reach the posterolateral surface of the femur just above the condyle. With this in view, the operator passes a carrier directly through the anterior incision into the joint which is made to penetrate the posterior capsule and to emerge in the lateral incision. The strip of fascia is then threaded into the carrier and pulled through the knee joint. When properly placed, it passes from its base immediately deep to the femur and then around the femur against the expanding portions of the condyle to pass over the normal attachment of the anterior crucial ligament. A drill hole is made through the tuberosity of the tibia, starting just anterior to the tibial spine The ligament is pulled through, and under firm tension with the knee at 170° it is fastened securely with silk ligatures to the anteromedial side of the tibia. When indicated, the end is continued upward on the medial side of the knee to lend additional support to the medial ligament. The knee wound is then closed in layers. The knee is put up in plaster in a position of 170° for four weeks. A brace is then fitted and exercises starting gradual extension of the leg are instituted The brace should be worn for from 8 to 12 weeks.

Gallie and LeMesurier's Method (Posterior Crucial Ligament). The authors feel that the following method of repair has distinct merit because (1) the operation is less traumatizing, (2) the possibility of a late developing traumatic arthritis is reduced, (3) the time of the operation is lessened, and (4) the newly formed posterior crucial ligament is entirely subsynovial.

1. The patient is first placed on his abdomen and the involved leg prepared for operation. Through a long medial incision which extends posteriorly to the upper portion of the calf, the tendon of the semitendinosus is exposed and isolated. It is then detached from the muscle as high as possible in the thigh and stripped downward to its insertion.

2. Through the superficial portion of a parapatellar incision, the insertion of the semitendinosus is exposed on the inner surface of the upper end of the tibia and the entire tendon drawn through to the front of the leg from beneath the sartorius.

3 The lower portion of the posterior medial incision is then deepened and the space between the gastrocnemius muscles located and widened until the posterior ligament of the knee joint and upper portion of the posterior surface of the head of the tibia come into view. Vessels and nerves are then retracted to the outer side. A quarter-inch hole is drilled obliquely downward and forward, starting from the posterior surface of the tibia just slightly external to the midline, and close to the attachment of the posterior crucial ligament to the bone. The drill emerges on the internal surface of the tibia close to the insertion of the semitendinosus. The cut end of the tendon is then threaded through the newly formed drill hole by the use of a bodkin, which thus presents the cut end of the tendon posteriorly.

4. A median parapatellar or split patellar incision is made after the patient has been turned on his back and the knee flexed over the end of the table at right angles. The bodkin is then pushed from behind forward through the posterior capsule and ligament of the knee at a point just above the hole in the head of the tibia and within the sheath of the posterior crucial ligament. The bodkin is then pushed forward until it presents through the synovial membrane

at its most anterior attachment to the internal condyle of the femur

5 A small incision is now made over the subcutaneous portion of the internal condyle of the femur and a quarter inch drill passed through the bone so as to enter the joint at the exact spot at which the bodkin had punctured the synovial membrane over the insertion of the posterior crucial ligament Flexible wire is then fastened to the end of the tendon after removal of the bodkin and pulled through the medial femoral condyle In this manner the entire tendon is subsynovial

6 The knee is then completely extended the tendon drawn taut and sutured to the internal lateral ligament The wound is closed in layers with silk

7 The knee is kept in complete extension for a period of two months after which time the plaster is removed and the knee mobilized At first there is very little motion due to the prolonged immobilization but within a period of two weeks the patient has regained about 100° of motion in the knee and the authors state that improvement is gradual but definite for a number of months thereafter

Campbell s Method (Posterior Crucial Ligament) The knee is prepared in the usual manner A segment of the quadriceps and patellar tendons and capsule eight inches in length is dissected down as in the operation for repair of anterior crucial ligaments A quarter inch drill is passed through the tibia just below the articular surface from its anteromedial to its posterolateral aspect and the drill point exposed by blunt dissection through a posterolateral incision The strip of tendon is drawn through the tibia and its free end pushed through the posterior capsule to the normal attachment of the ligament into the anterior compartment of the knee A drill hole is then made through the medial femoral condyle to the normal anterior attachment of the posterior crucial ligament and the free end of the new ligament is drawn through and sutured to the upper border of the internal lateral ligament through a third small incision

[There are detailed here numerous operative procedures They vary little if at all in principle but rather in technical details Each of them is reported as being a satisfactory procedure It can be safely said however that in general they are being used less and less and are today reserved for cases which resist intelligent conservative attempts to gain knee joint stability through re establishment of muscle balance See comments on knee joint stability p 1052 this chapter Ed]

ALAR FAT PAD

Anatomy and Functions

The alar or infrapatellar fat pad lies beneath the patellar tendon and acts as a cushion and as a lubricator of the joint proper

Hypertrophy

The most common internal derangement affecting the fat pad is hypertrophy of this part It is generally believed that the cause of this condition is either repeated trauma in cases of young individuals or a chronic arthritis of the knee joint in cases among the older age groups As a result of these conditions the fat pad is enlarged fibrous thickened and in some cases partly calcified In cases in which the quadriceps have become atrophied from disuse or disease the pad is often pinched during the act of extension This causes hemorrhagic areas in the region of the fat pad which sometimes become fibrotic

The signs and symptoms of hypertrophied alar fat pads usually consist of pain behind the ligamentum patellae dull ache behind the patella especially after walking or extreme exercises and stiffness or weakness of the affected joint Fisher reports that with recurrent attacks of injury to the alar fat pad a sudden stabbing pain or sensation of giving way of the joint not

usually amounting to true locking, may occur.

On examination, swelling about the patellar tendon and tenderness to deep pressure on either side of the ligamentum patellae are found. This tenderness persists when the knee is brought into complete extension. Another condition which exists coincidental with hypertrophic fat pads is a marked atrophy of the quadriceps muscles.

In spite of the seemingly obvious signs and symptoms, the diagnosis of an injured alar fat pad is not a simple matter. Very frequently the surgeon is not aware of the presence of the lesion until the time of exploration. Not uncommonly diagnosis of a torn meniscus is made only to find a pinched alar fat pad as the offending lesion.

Treatment. As Sir Robert Jones, Fisher, and Osgood have pointed out, the main object of the treatment is to prevent further injury to the alar fat pad. A number of forms of treatment have been suggested for this condition, among which are raising the heel on the affected side so that the knee cannot go into complete extension, thus preventing further pinching of the fat pad. The same result may be obtained by wearing a caliper brace with a lock limiting extension about 20°, as described by Jones and Lovett. It must constantly be kept in mind that exercise of the quadriceps is imperative so as to increase the pull of these muscles on the capsule during the process of extending the joint. This pull is transmitted to the alar fat pad, and consequently is a very definite aid in reducing internal trauma. A valuable suggestion made by Osgood is that all exercises should be done without weight-bearing in order to prevent any further squeeze of the fat pad.

If the symptoms do not disappear in a reasonable period of time by using conservative methods, it becomes necessary to remove the fat pad surgically. One can make either a medial parapatellar incision for complete exploration of the knee joint as recommended by Darrach and others, or a small medial or lateral incision depending upon the area of symptoms. Because of the difficulty in diagnosing these conditions, the larger incision is recommended. A good exposure is essential, and as no functional disability results it is advisable to do a complete removal of the fat pad.

The after-treatment of such a condition is the same as that recommended for torn medial menisci.

TIBIAL SPINE

Anatomy and Functions

The tibial spine is an intercondylar bony eminence to which the anterior crucial ligament is attached. The mechanism which produces internal derangements relative to this structure is usually the same as that which causes a tear of the anterior crucial or a tear of the medial meniscus.

Injuries

Injuries of the tibial spine are considered in the same group as ruptures of the crucial ligaments. It will be remembered that the anterior crucial ligament attaches to the inner of the two tibial spines. Avulsion of the tibial spine is produced by the same mechanism which produces a rupture of the anterior crucial ligament. If the tibial spine is avulsed, the anterior crucial ligament usually is not ruptured.

The signs and symptoms are identical with those of the anterior crucial ligament tear, but the most characteristic sign is a firm bony block to full extension. This is in contrast to limitation of extension caused by a torn meniscus where the block to extension is cartilaginous in type. Usually an avulsion of the tibial spine will be accompanied by a tear of the internal lateral ligament. The lower leg can be hyperextended upon the upper leg and the tibia displaced forward.

Treatment. The method of treatment of crucial ligament tears and avulsion of the tibial spine certainly has not been definitely

agreed upon Probably the most important factor in treatment is building up the quadriceps extensor muscles so that they compensate to a marked degree for the weakness and instability caused by the loss of action of the crucial ligaments Conservative treatment should certainly be tried for a period of time rather than immediate operative intervention

If fractures of the tibial spine can be adequately reduced and held in position by complete extension of the lower leg upon the femur conservative methods of immobilization by plaster from groin to ankle are indicated

In cases where adequate reduction cannot be accomplished operative intervention through a medial parapatellar incision is indicated The tibial spine should be sutured back into normal position by use of fine strong wire After operation the knee should be immobilized for five to six weeks in circular plaster to allow the bone to firmly unite in normal position

[Gross displacement with instability of the joint is the indication for operation —Ed]

OSTEOCHONDRITIS AND LOOSE BODIES IN KNEE JOINT

The etiology of loose bodies in the knee joint is manifold Loose bodies may be masses of uric acid salts osteomyelitis sequestra lipoma tumors of the capsules as in chondromatosis hypertrophic synovial villi clots which are organized hemangiomas or fragments of torn menisci The classic condition of osteochondritis dissecans also falls in this group

The condition usually exists in patients between 30 and 40 years of age and the patient himself can usually tell that he has a loose body in the knee There usually is a history of injury and most frequently a torn meniscal type of injury There is usually locking with intervals between the episodes though the locking is not so severe as in torn menisci and the pain is often referred to different parts of the joint rather than localized as in the case of a torn meniscus One should always obtain a two plane x ray of the involved joint preferably anteroposterior and lateral stereoscopic views in order to determine the exact location of the loose body If purely cartilaginous it cannot be visualized

Treatment Treatment consists of surgical removal so as to prevent progressive injury to the knee joint If a loose body is left for any period of time within the joint definite traumatic arthritis will inevitably result The presence of loose bodies causing symptoms is usually sufficient evidence to warrant an arthrotomy

The best approach is a wide parapatellar incision designed for complete exploration If the loose body is in the posterior compartment the procedure necessary to bring it into view is to extend the knee and then knead it upward in the hope of pushing the body into the suprapatellar pouch However if the offending body cannot be found through the anterior incision by the exposure already mentioned a posterolateral incision as proposed by Henderson (see knee joint approaches earlier in this chapter) may be used for exploration of the posterior chamber Posterolateral incisions are made with the knee flexed to a right angle thus relaxing the posterior capsule A semilunar incision with the convexity anteriorly or posteriorly may be made in the skin and a straight incision parallel with the longitudinal axis of the leg made in the capsule The incision on the external aspect is just outside the biceps tendon and on the internal aspect is just anterior to the tendon semitendinosus After the skin incision has been made the knee is moderately flexed so as to draw the tendon out of the way and make the capsule readily accessible After removal of the loose body no postoperative immobilization is required As soon as the incision is healed the patient is started on active motion so as to keep up the quadriceps extension power and

maintain good stabilization through the ligaments and muscles of the knee as is done after meniscus removal. [At the time of removal of the loose body, all hypertrophic spurring should be removed, degenerated or softened areas of articular cartilage should be shaved down to normal tissue, and any other pathologic finding should be taken care of.—Ed.]

HYPERTROPHIC CHANGES IN KNEE JOINT

Hypertrophic changes usually occur in people about 40 years of age with a history of arthritis from one cause or another. The presence of hypertrophic changes is characterized by recurrent sudden attacks of pain which is not of a severe nature. There is usually a marked effusion into the joint with localized swelling on both sides of the patellar tendon. Severe attacks of locking do not occur, but interference with free joint motion is frequently noticed. Motion usually gives pain. Palpation reveals the joint capsule to be thickened and the localized swelling to be of a variable degree of resistance. There is slight tenderness on deep pressure as well as marked crepitation. There is often an increased blood sedimentation rate. Not infrequently the patient suffers from a generalized rheumatoid arthritis.

Treatment. The conservative type of treatment in such cases is chiefly protection of the involved joint. Strapping of the anterior aspect of the knee with adhesive tape is efficient in moderate cases though a posterior molded splint is often used to effect immobilization. Complete rest and the elimination of any possible foci of infection is always advisable in addition to building up the patient's general resistance. If the symptoms remain severe after a reasonable course of nonoperative treatment, operative intervention with joint débridement as recommended by Magnuson must be considered. [For further details of the handling of arthritic joints see Chapter 15.—Ed.]

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39

Fractures of Shafts of Tibia and Fibula

RALPH G. CAROTHERS, M.D.

VARIETIES AND DIAGNOSIS

These fractures may be of any variety from simple fractures of the shaft of one bone with no displacement, to long spiral fractures, severely comminuted fractures, or section fractures. In no pair of bones do such combinations of fractures occur at such different levels, and the diagnosis is never certain unless the whole of the shaft of each bone has been seen in the x-ray film. The deformity may vary from none at all to marked overriding angulation and rotation In addition to an accurate diagnosis of the bone injury, the character of the nerve and blood supply of the foot must be investigated and noted

TREATMENT

The sooner the treatment is initiated the better. It makes little difference which of the methods of treatment about to be described is contemplated. There is nothing to be gained by delay. Blebs may form quickly in any of these cases, thus eliminating the possibility of open reduction, increasing the hazard of the use of pins and making it necessary to pad, thus diminishing the effectiveness of a circular plaster. In addition, it must not be forgotten that the tibia lies just under the skin, and a simple fracture may become compounded while the leg is supposedly firmly fixed in a temporary splint.

The treatment, of course, consists of reduction, fixation, and finally restoration of function, but as there is considerable overlapping in these three phases of the problem, they will be considered together as follows (1) The plaster method, (2) the pin-fixation method, and (3) the internal fixation method

1. Manipulation and Plaster. The use of plaster alone is applicable when there is little or no deformity, or after the deformity has been corrected by manipulation In such a case the plaster should be applied directly to the skin, and should extend from beyond the toes to the groin, with the ankle squarely at a right angle, *and the knee flexed to about 135°*.

[It may be safely said that no fracture of both bones of the leg, immobilized by plaster alone, should have the knee free before beginning union can be at least clinically demonstrated. The knee should invariably be flexed to an angle of *at least* 135° under the following conditions: (1) Any obliquity to the fracture line, (2) any comminution, including a single intermediate fragment, and (3) any tendency to slip in a transverse fracture during reduction or during the application of the leg portion of the circular plaster or of the molded splints.

It is the opinion of many men experienced in fracture treatment that flexion as described is desirable in all fractures of both bones of the leg in which reduction has been necessary.—Ed.]

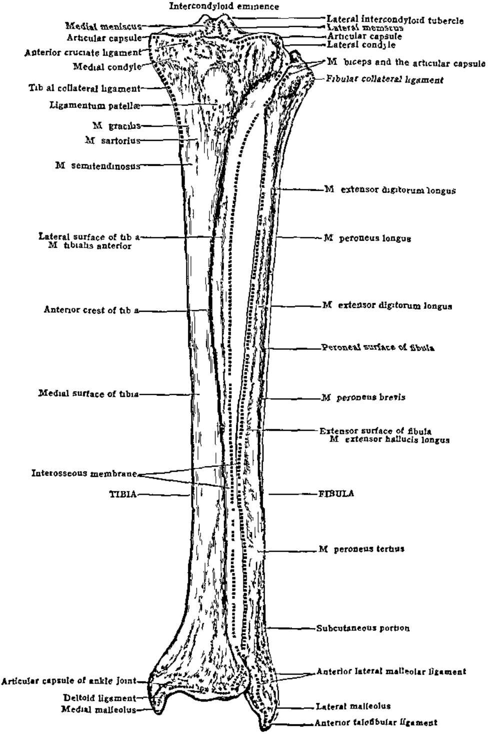


FIG 875 A Left tibia and fibula anterior view (Courtesy Morris Human Anatomy edited by J P Schaeffer, 10th ed , Philadelphia The Blakiston Co)

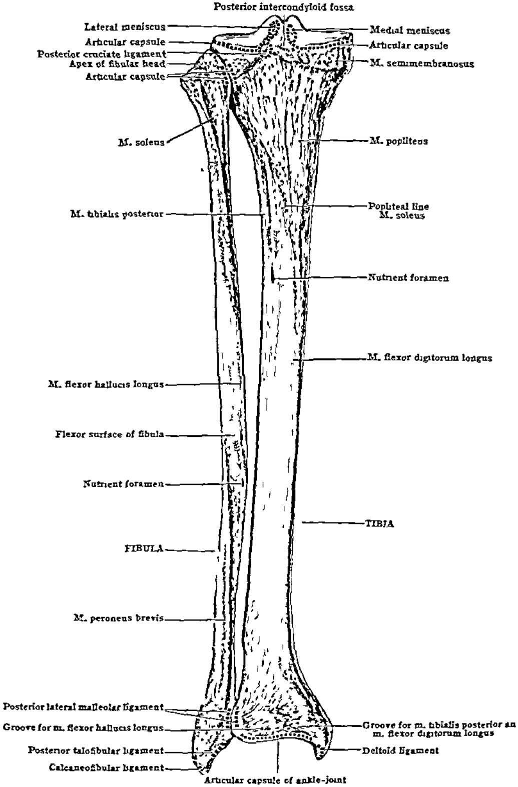


FIG. 875 B. Left tibia and fibula, posterior view. (Courtesy, Morris' Human Anatomy, edited by J. P. Schaeffer, 10th ed., Philadelphia, The Blakiston Co.)

A simple method of applying such a plaster encasement is for one assistant to support the foot by placing the palm of one hand under the heel and with the other to grasp the toes A second assistant supports the limb at the site of the fracture with both hands A narrow strip of sheet wadding should surround the leg at the level of the fracture in order that the plaster may be cut at this point for wedging should angulation occur while the plaster is being applied A long slab of plaster is applied to the posterior surface extending from beyond the toes to a point high on the thigh and the encasement completed by smoothly wrapping on sufficient plaster bandages The two assistants can carefully shift hands back and forth as the plaster is being applied so that there is never any loss of support and at the same time there is no direct pressure at a single point which might later cause a pressure sore The posterior slab should be at least eight layers in thickness and should be well rubbed before application Each turn of the bandage should be well rubbed in and if this is done the plaster may be light and yet quite strong

When the wrapping is finished the leg should be placed on a pillow and the assistant should continue to support the ankle in its position until the plaster has dried If the pillow is of rubber or of any other waterproof material either a blanket or many layers of newspaper should be inserted between the rubber and the plaster to absorb the moisture Films are made as soon as possible and if any angulation has occurred the plaster should be cut two thirds of its circumference at the level of the fracture The center of the uncut part should be directly over the point of the angulation The encasement is then wedged and sealed (Fig 878)

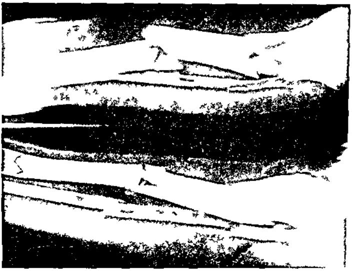


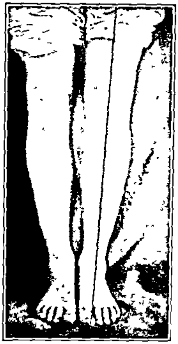
Fig 876 Two x rays of same leg only one of which shows lower fracture of tibia If x rays are incomplete it is very easy to overlook second and third fractures

A method of applying a circular plaster to fractures in which reduction has not been necessary is to sit the patient on a table with his leg hanging over the edge The toes rest on the surgeon s knee In this position the plaster is run up to the tubercle of the tibia When this part of the plaster has set the encasement is extended well up the thigh with the knee moderately

flexed. It is wise, when applying the plaster in sections, to place a narrow strip of sheet wadding under the edge of the first section before applying the second The new position the leg assumes when the second half of the plaster is applied may otherwise permit the first half, now already dry, to cut into the skin at its edge (Figs. 879 and 880).

The patient is put to bed with the whole leg elevated, and close watch is kept for circulatory disturbances of the toes. Ordinarily it is not necessary to split such a plaster, but if too much swelling occurs, splitting can most easily be accomplished by running a plaster cutter down the front of the thigh, passing then between the patella and the condyle of the femur, and then down the side of the leg to a point behind the malleolus. Starting again on the side of the foot, another cut is made to meet the first in the space just under the malleolus Thus the plaster is cut in its thinnest part and bony prominences are avoided.

Any of the above-described encasements may be considered satisfactory for fractures of the leg They are applicable in any case in which an accurate reduction has been accomplished, correcting all deformities, including rotation But the application may be further varied under certain circumstances. If the fracture is of the transverse variety, the knee may be splinted at 170° instead of 135° and a walking iron or heel applied within a week. But if the fracture is oblique or comminuted, the knee should be flexed to about 135°. If the fracture is purely transverse and above the junction of the middle and upper thirds, the foot part of the plaster may be eliminated. This type of encasement must be skin-tight except at the lower edge, where a circular strip of thin felt or sheet wadding about one inch wide is used to protect the skin from the lower edge of the plaster. If any other padding is used, the plaster will slip down and cut at the ankle. An Unna paste boot must first be applied to the foot when this type of encasement is used, since otherwise swelling of the foot and ankle may occur. This type of plaster makes walking easy and preserves the function of the ankle. It is also



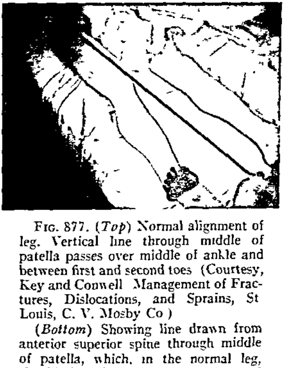


FIG. 877. (*Top*) Normal alignment of leg. Vertical line through middle of patella passes over middle of ankle and between first and second toes (Courtesy, Key and Conwell Management of Fractures, Dislocations, and Sprains, St Louis, C. V. Mosby Co)

(*Bottom*) Showing line drawn from anterior superior spine through middle of patella, which, in the normal leg, should drop between first and second toe. This fractured leg is deformed by external rotation and angulation.

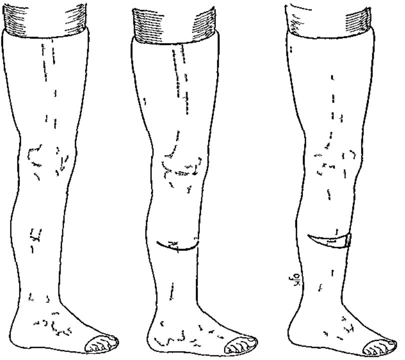


Fig 878 Wedging a plaster to correct angulation A linear cut is opened to a wedge held by a wood block and after confirming position by x ray gap is repaired with plaster (Courtesy Jour Bone and Joint Surg 14 603)

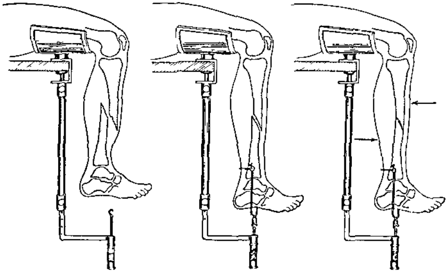


Fig 879 Watson Jones tibia traction apparatus consists of a thigh support clamped on to any table to which is fixed an L-shaped traction bar with coarse adjustment and rotating handle with fine adjustment Length and alignment is secured by the apparatus while limb hangs in the line of gravity Apposition is maintained by pressure of operator's hands (Courtesy Watson Jones R Fractures and Other Bone and Joint Injuries 3d ed Baltimore Williams and Wilkins Co)

useful in cases in which union is slow and stimulation by weight-bearing is desired It will prevent angulation but will not prevent collapse of comminuted fragments and will not prevent overriding and rotation of a spiral fracture, and therefore should be reserved for old fractures in which there is some union or for transverse fractures high up, and for fractures of the fibula only (see Fig. 888).

There is still another way of applying plaster when some traction is needed. The knee is flexed, and a sling placed under the knee is fastened to some secure object. A hitch of bandage is placed around the well-padded ankle and traction is applied in the long axis of the tibia. The plaster is then applied from the ankle to the knee, then from the knee up the thigh, and lastly to the foot (Fig. 890).

[The application of unpadded circular plaster is not the only method of plaster immobilization available. A posterior molded and a sugar-tongs splint can be used, as described in detail in Chapter 22. If they are applied with some form of woven elastic bandage, they are theoretically inclined to adapt themselves to any changes due to increase or decrease in the swelling of the part with resultant minimal risk of circulatory difficulty or slipping of the fragments. They must be inspected frequently to insure adequacy of the bandaging This necessity may be regarded as an advantage. Four-inch plaster should be used, and the directions for the making of plaster splints given in Chapter 22 should be carefully followed. —Ed.]

2. Single-pin Method. Comminuted fractures, and fractures with overriding, cannot be held as a rule in good position while the plaster is being applied unless strong traction is maintained. In these cases skeletal traction should be used. The simplest type of single-pin application is described by Watson-Jones (Figs. 879 and 880). A local anesthetic must be used. [See local anesthesia in fractures, Chapter 22.—Ed.] A pin is driven transversely through the lower fragment of the tibia at a point just above the ankle joint. A "U" is fitted to the pin and the leg is hung over the edge of the table in a vertical position. Traction is then applied until the leg is taut, while the position of the toes is maintained by the surgeon's knee. In this way the ankle is

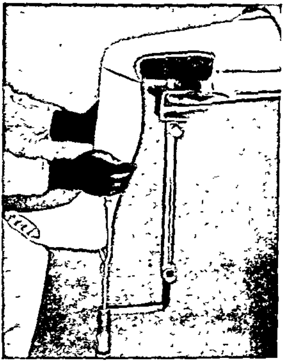


FIG. 880. Tibia traction apparatus showing operator's grip while plaster is setting. (Courtesy, Watson-Jones, R.: Fractures and Other Bone and Joint Injuries, 3d ed., Baltimore, Williams and Wilkins Co.)

kept at a right angle and the rotation is corrected The fragments are then molded into position by the hands, and the plaster is applied up to the knee. It is then completed to the groin as soon as the lower half has set, while the traction is maintained, the knee being kept flexed to at least 135°. Again, it is wise to apply a little sheet wadding at the level of the fracture, for subsequent wedging, and a little more at the upper end of the lower section of plaster. These strips must be narrow so that as

much of the plaster as possible sticks to the skin

Another way to apply a similar plaster encasement is to use a spring caliper inserted into the os calcis and to exert traction on the leg with the knee flexed over a gas pipe frame (Fig 881) This is the standard Bohler method

holds the foot at a right angle and since the patient is supine an anesthetic may be used

In either case the patient is put to bed with the leg on a bent frame (Fig 882) and 10 to 15 pounds traction is maintained for from five to six weeks If swelling has not occurred before the treatment is

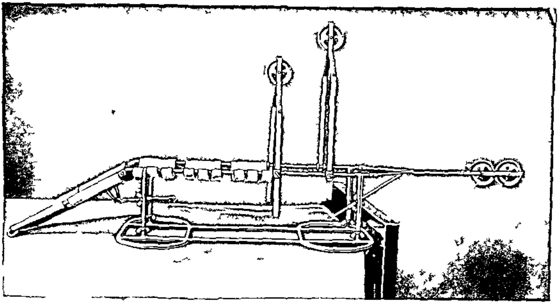


Fig 881 Bohler Braun leg splint Femur portion is adjustable in length and angle of elevation No rods or parts interfere with bedpan Pulley arches are adjustable longitudinally and vertically Tandem pulleys on forward end are also adjustable longitudinally and vertically All thumb screws are nonremovable

In applying adjust canvas slings to fit contour of posterior surface of leg Adjust length of femur rods so that outer rod extends up to trochanter and inner rod about one inch below perineum Desired angle of femur is obtained by manipulating wing nuts on the four threaded posts and also wing nut on the femur supporting threaded rod Rear pulley arch is placed at a point where traction will be in direct line with femur Forward pulley arch is placed near ankle as a means to hold foot at right angle to long axis of leg (Courtesy Zimmer Mfg Co Warsaw Ind)

There are advantages and disadvantages to each method In the Watson Jones method the leg is vertical and therefore backward bowing will not occur It is however more difficult to put a pin through the tibia than to apply a spring caliper to the os calcis The removal of the caliper is less dangerous than is pulling a pin through the bone In addition the pull through the os calcis tightens the tendo achillis and

begun it may be necessary to split the plaster If swelling has already developed the plaster will become loose In either case a new encasement is applied when the circulation has reached normal The same traction is maintained while the old plaster is removed and the new one applied and x ray or fluoroscope is used to check position Angulation is corrected by wedging of the plaster when necessary

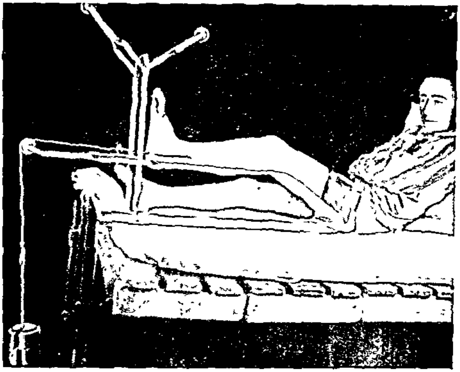


FIG 882 In unstable fractures and all fractures with severe swelling the transfixion pin is incorporated in the plaster and continuous traction is maintained for from five to six weeks (Courtesy, Watson-Jones, R: *Fractures and Other Bone and Joint Injuries*, 3d ed, Baltimore, Williams and Wilkins Co.)

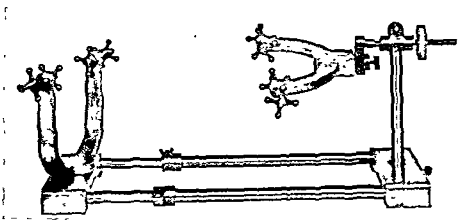


FIG 883. Griswold's extension apparatus. Lateral view. (Courtesy, Scudder, C. L.: Treatment of Fractures, 11th ed., Philadelphia, W B Saunders Co.)

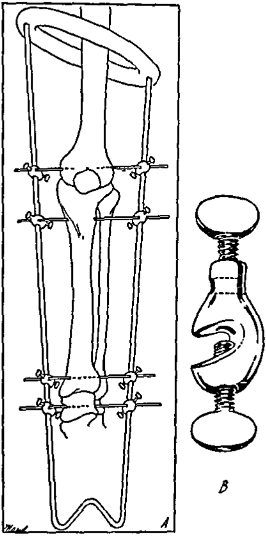


Fig 884 Drawing showing method of fixation and traction (A) by using Steinmann pin (B) fastened to sides of Thomas splint with Caldwell s pin lugs (A) Shows pin through condyles of femur, through tibia at level of tubercle, through tibia at ankle, and through os calcis (Courtesy, Caldwell, J A Manual of the Treatment of Fractures, Springfield, Ill, Charles C Thomas, Publisher)

[For details of technic of pin or wire insertion, see Chapter 22]

[A single pin or wire in the lower tibia or heel gives greater security in maintenance of position than does simple plaster, *provided the knee is adequately flexed* It does not, however, insure rigidity of fixation at the fracture site as many men mistakenly believe, since pivoting on the single pin is possible and since the plaster no matter how snugly applied, is more or less separated by an elastic and compressible soft part cushion from the bone fragments which it is designed to hold fixed and immovable The same holds true, to a less degree, when a single pin or wire is put through each fragment, and incorporated in plaster Maintenance of position and rigidity of fixation are not synonymous terms —Ed]

3 Multiple-pin Method There are several pieces of apparatus on the market (Fig 883) designed to distract the fragments by screw or turnbuckle traction between two pins, one in each fragment The author has developed a simple and cheap method It is applicable in simple as well as in compound fractures and completely eliminates any need of worry over swelling or over herniation of a wound which requires dressing

Two pins are put through the upper fragment about two inches apart parallel to each other, transversely to the long axis of the bone and with the patella pointing directly upward A third pin is driven through the os calcis parallel to the upper pins after the foot has been rotated into normal relation with the knee These three pins are then locked with the Caldwell pin lug (Figs 884, 886) to the bars of a Thomas, Braun Pierson, or any other suitable splint which has round bars The upper pin is locked first Then traction is put on the lower pin until the desired length is attained then it, too, is locked Finally the middle pin is locked The reason two pins are used in the upper fragment is to prevent rotation of this fragment around a single pin If the lower pin is in the os calcis, the foot will be supported by traction through the tendo achillis and no rotation on the pin will occur If, however, one wishes to put the lower pin through the tibia, then two pins should be used here as well, making

four in all, just as in a leg-lengthening operation. [See editorial comment on pin fixation preceding this paragraph, and also discussion in Chapter 22.—Ed.]

As the pins are locked, the fragments are molded into position and the traction is adjusted either on the pin as a whole or on one side to gain proper alignment. If all pins have been put in parallel with one another, and the foot has been properly rotated before the lower pin has been inserted, the lower fragment will be properly rotated in regard to the upper, and one need be concerned only with length and angulation, which can be adjusted by altering the set of the pin lugs. The author has made a splint with a ring at the distal end so that the lower fragment may be rotated at will. In this case, the lower pin is locked first and the pull for length put on the upper pin (Fig. 885). The patient is put to bed with no dressing at all, even in compound fractures, if the latter have been closed. It makes little difference how much the leg swells, there will be no displacement of the fragments. We have had more than one case develop tetanus in such a splint, yet the fragments were not displaced in the convulsions, and one mental patient walked around the ward with this splint on and did no harm to his leg. We have also successfully carried several patients through gas-gangrene infections when so splinted. Plaster is applied as soon as the swelling has subsided, or, in compound fractures, when the wound has reached a point when it may safely be sealed (Fig. 887).

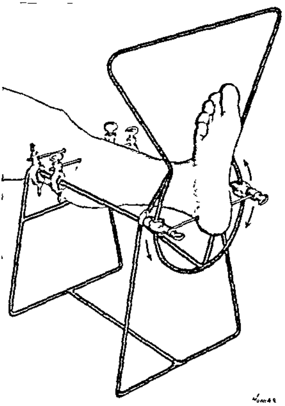


FIG 885. Author's frame for treating fractured leg with three pins.

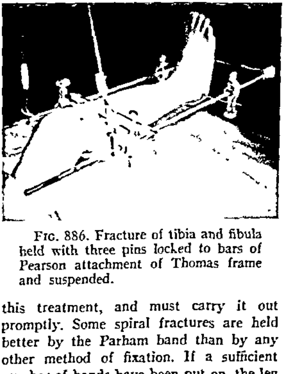


FIG. 886. Fracture of tibia and fibula held with three pins locked to bars of Pearson attachment of Thomas frame and suspended.

[For details as to technic in the use of various recognized methods of skeletal fixation, including the Haynes, Stader, and Roger Anderson appliances, see Chapter 22. —Ed.]

4. **Internal Fixation.** This may be the best method of fixation and the best method of treatment theoretically, but it should not be attempted unless one is fully equipped to do this work. Further than this, one must make up his mind early if he elects to use this treatment, and must carry it out promptly. Some spiral fractures are held better by the Parham band than by any other method of fixation. If a sufficient number of bands have been put on, the leg

FIG 887 (*Left*) Plaster cast has been put on after fracture was held with pins Note projection of pin ends through plaster

FIG 888 (*Right*) Plaster cast with Unna paste foot piece

may be left without any splinting whatsoever These bands are very easily introduced with a grooved director and will hold the bones in excellent position However if a sufficient number of bands have not been applied to hold the fragments firmly or if the spiral is too short for a sufficient number of bands then a plaster encasement becomes necessary in addition to the open operation If as so often happens in such a case there is some shortening the upper point of the lower fragment should be cut off with a rongeur bone

FIG 889 Plaster cast showing correct angle of knee and ankle

cutting forceps removing about one half inch Then using an elevator in the medulla of the upper fragment pressure against the cut end of the lower fragment will cause the tibia to lengthen sufficiently to get a perfect reduction If however the fibula has been impacted at a higher level it may occasionally be necessary to cut the fibula Short oblique fractures should be fixed with screws put through at an angle as a Parham band will slip off in such a case In the oblique fracture usually a plate is necessary in addition to the screws to maintain sufficient hold on the fragments

On the whole the fractures in which internal fixation is most valuable are the compound fractures It has been rather generally held that metal should not be put into an infected or contaminated wound but it must be remembered that metal itself has never caused infection and if immobilization can be made more perfect by introducing an internal splint then there is less likelihood of infection occurring than there is with less perfect immobilization by ex

ternal means. The compound fracture is already open, and unless it is of the transverse variety, in which the fragment can be jammed into place, may in many instances be held by plate, band or screw, or a com- that, of all fractures, the compound is the one which must be held securely more than any other and the one which must be most promptly dealt with

One other point in regard to the com-

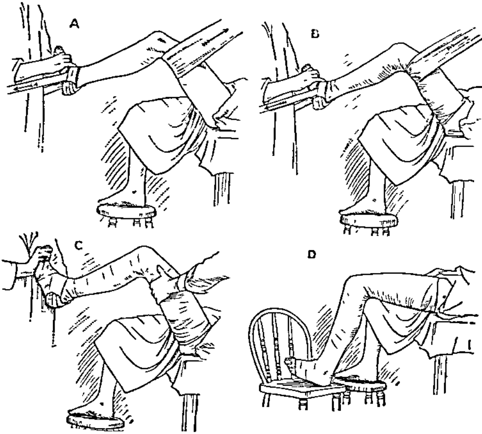


FIG. 890. Reduction of fracture of leg by traction method (A) Traction is obtained by passing a piece of bandage about ankle in form of a clove hitch. a soft pad of felt being interposed between it and the skin Ends of bandage are knotted about hips of an assistant, who supports foot manually and exerts traction by inclining body backward. Counter-traction is obtained by a supporting band passing around lower part of thigh which holds knee flexed (B) In this position a plaster casing is applied in section. First section extends from ankle to groin, space being allowed for removal of counter-traction band (C) When this has hardened, traction bands are removed and foot is supported manually while remaining portion of plaster is applied. (D) Plaster completed. (Courtesy, Scudder, C. L · Treatment of Fractures, 11th ed., Philadelphia, W. B. Saunders Co.)

bination of these. It is true that this metal may have to be removed later, but the more perfect immobilization gained by its introduction is well worth while if thereby it helps prevent infection. This is not the place to discuss the general theory of compound fractures, but it must be stated here

pound fracture should be remembered. If one is prepared to close the wound completely, he should do this without tension, and, in order to accomplish this, it may be necessary to make relaxing incisions well to each side of the original wound. These incisions should be made down to the fascia,

and should allow the skin to retract sufficiently to permit the original wound to be closed without tension Thiersch grafts should be put on the releasing incisions at once (see Chapter 22)

In the section fractures in which an intermediate section of the whole shaft is separated by upper and lower fractures it

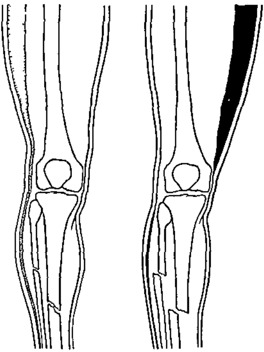


Fig 891 Drawing on left shows normal reduction of fracture Dotted area is approximate amount of shrinkage which will take place in thigh Figure on right shows displacement occurring in leg after this shrinkage has occurred and cast is permitted to fall away from inner side of thigh If cast is drawn back to inner side of thigh and space on outer side filled with cotton wadding as indicated by figure on left fragments are restored into good position again (From personal communication with Laurie McKim Montreal Quebec Canada)

may be essential to fix one fracture internally thus reducing the number of movable fragments When internal fixation is used at all it is ideal to fix the fragments so that no external splinting is necessary This may require several screws with the addition of bands or plates When such a combination of items is used one must be sure all are of the same metal

[For a detailed discussion of the operative reduction and fixation of fractures and of the handling of compound fractures see Chapters 22 and 23 The operative procedures cited here by the author are in common use but many surgeons who do a great deal of operative fracture work will disapprove of the procedures though in agreement with the principles expressed The whole matter is thoroughly gone into in the chapters cited above Ed]

AFTER TREATMENT

As soon as swelling has subsided the patient may be permitted up on crutches If the fracture is transverse a walking iron or heel may be applied and weight bearing instituted early If however the fracture is oblique or spiral weight bearing should not be allowed unless there are pins above and below the fracture which have been imbedded in the plaster When cases have been treated by internal fixation and without plaster all manner of movement is permitted but weight bearing is not allowed until union is firm

The time required for union varies greatly in these cases and one must be guided by the x ray findings As a rule however it takes not less than eight weeks and frequently may take much longer In the ordinary cases the plaster should be removed at the end of ten weeks and the state of union clinically observed and tested If union is clinically firm the patient may be allowed to get about then with an Unna paste stocking extending to the knee But if union is not firm a new plaster encasement should be applied In this instance the plaster with an Unna paste footpiece may be used and weight bearing permitted with function of the ankle

Of all the muscles in the body none atrophy more quickly when not used than

the quadriceps group in the thigh. From the very beginning, therefore, the patient should be instructed to contract these muscles and try to preserve the tone. Even if the plaster does not permit movement of the knee, muscles can be used by voluntary contraction carried out by the patient. If this is done, post-fracture physiotherapy will not be necessary.

Laurie McKim of Montreal has pointed out that in using plaster on fractures of the tibia and fibula, even though a very snug hold is maintained at the knee and the ankle, the thigh muscles become atrophied. When a fair amount of atrophy has taken place, one sees that the plaster encasement is quite loose in the thigh portion and this permits lateral displacement of the upper part of the plaster. As there is no atrophy of the knee itself, this lateral displacement is transferred to the leg, causing displacement of the upper fragment of the tibia. This always occurs in an inward direction. It is therefore necessary, every week or so, to cut the outer half of the plaster away from the thigh from the top of the encasement to the knee level and to apply a new half of plaster which fits more closely, thus drawing the thigh snugly against the mesial side of the encasement. When this is done, the knee acts as a fulcrum and the upper fragment of the tibia is moved outward to its original position (Fig. 891).

It must be remembered also that as soon as the plaster has been removed from the lower limb, the whole leg swells on dependency. The leg will become edematous if this is not prevented, and limitation of motion of the joints will develop which will be very difficult to overcome. An elastic bandage or an Unna paste boot should be applied as soon as the leg is allowed to become dependent after the removal of plaster. In the case of internal fixation without plaster, this may not be necessary if good function of the joints and muscles is maintained while the patient is in bed, but he should be watched when he first begins to hang his leg down. If swelling develops, an elastic bandage or stocking should be applied, and should be worn until circulation is normal. [See Chapter 22 for use of physical therapy in after-treatment of fractures.—Ed.]

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40

Fractures of Ankle and Foot

Otto J Hermann, M D

Fractures of Ankle

ANATOMY

A brief review if only by drawings etc of the local anatomy of the ankle is a fitting introduction to the subject of ankle fracture therapy The following illustrated figures are therefore included merely to refresh the surgeon s mental picture of the essentials of the surgical anatomy of the ankle and to act as goals to be striven for in the reduction of fractures in that region They may also serve to show why certain manipulations moldings etc are stressed in this treatment (Figs 892 893 894)

General Remarks At the outset it must be emphasized that in order to obtain accurate reposition in ankle fractures especially in the more complicated types it is essential to institute the manipulation reduction and fixation at the earliest possible time after the injury This includes those cases in which there are present such soft tissue complications as swelling bleb formations or abrasions As will be pointed out later such cases can be reduced the complications treated and then put into a temporary type of fixation which is adequate and can be retained until it is deemed safe to apply a more permanent type of fixation On the point of early reduction etc McBride[1] has stated that Waiting for swelling to diminish or for blebs or severe abrasions to heal before reducing fragments has been the cause of more permanently disabling results in fractures of the tibia and fibula than any other factors

Accurate reduction is especially important in those complicated ankle fractures which include the lower anterior or posterior tibial margins Incomplete repositions in these cases are most apt to give painful feet and ankles on weight bearing But it must also be remembered that good initial reductions and fixations of ankle fractures can go to poor end results with unintelligent after care Following a good reposition the type of fixation must be carefully chosen—it should be adapted not only to the type of fracture but also to the degree of intelligence of the patient Surgeons connected with large charitable institutions are as a rule cognizant of this factor It is felt however that it has not been sufficiently stressed in the past

In these general remarks it may also be well to note that the position of election in regard to the foot after reduction of the fracture or fracture dislocation is about at a right angle natural position But it is further to be noted that this position may have to give way to dorsal or plantar flexion or the right angle may be coupled with some inversion when the occasion demands for maintenance of reduction or for a later stronger foot

Finally, in the convalescent care of ankle

fractures, under- and overtreatment must be guarded against. For example, a simple unilateral or isolated injury to the ankle (as a fractured external malleolus) may be given unnecessary prolonged fixation, or, on the other hand, a complicated ankle fracture (such as a bimalleolar fracture of the ankle with a posterolateral dislocation and a marginal fracture of the tibia at its inferior posterior lip) may be allowed too early unprotected direct weight-bearing.

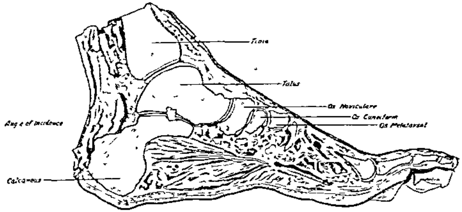


FIG 892. Schematic drawing of ankle and foot, lateral view, intended to illustrate some of the main features of surface anatomy in relation to underlying osseous structure.

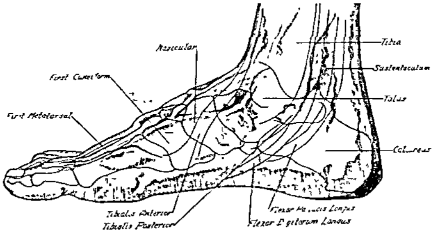


FIG. 893. Mesial view of Fig 892.

TREATMENT

Treatment of the simpler types of ankle fractures proceeds to that of the more complicated ones—i.e., proceeding from the (1) *simple unilateral ankle fractures without* displacement or injury to the opposite side, through the (2) bilateral fractures without displacement, to the (3) more complicated fracture-dislocation types.

I. Simple Ankle Fractures, Where Injury Is Unilateral and Without Dislocation

Clinical evidence plus x-ray examination will tell us whether the injury is unilateral or not. A clinical test as described by W. G. Campbell[2] of England is quite useful here:

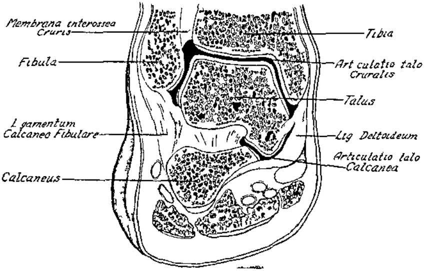
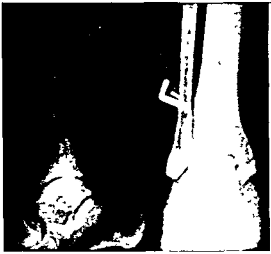


FIG 894 Coronal section of ankle and foot depicting lower tibiofibular joint talocalcaneus joint and the various ligaments The picture of the ankle mortise as given is a good one to retain as a mental picture when dealing with traumatic widened ankle mortises and in traumatic cases where there is diastasis

FIG 895 (*Left*) Fracture of external malleolus This case had no displacement and no injury to outer side of ankle

FIG 896 (*Right*) Fracture of internal malleolus This case had no displacement and no injury to outer side of ankle



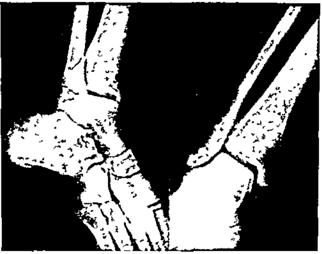


FIG. 897. (*Left*) Fracture of internal malleolus Here there was no displacement and no injury to outer side of ankle.

FIG. 898. (*Right*) Transverse fracture of external malleolus. In this case there was no displacement and no involvement of inner side of ankle.

. . . grasp the foot and attempt to push the foot as a whole towards the fractured bone No twisting must be done or the test is vitiated. If the ligament is injured, the patient immediately winces, and feels pain in the fracture.

Such ankle fractures as these are: (1) Spiral oblique fracture of the lower end of the fibula with no involvement of the mesial side of the ankle (Fig. 895); (2) fracture of the internal malleolus with no displacement (Figs. 896 and 897); and (3) fracture of the tip of the external malleolus (Fig. 898).

Such fractures are often overtreated. Their treatment is quite simple and, generally, requires no general anesthetic. Some of the cases may be put at once into their final fixation while others may require a preliminary rest for a day or so in a pillow splint (Fig 899) until the swelling has subsided before the regular fixation is applied.

Fixation. The fixation consists of circular plaster of paris extending from the tibial tubercle to the toes. It is snug-fitting, being padded only with an encircling band of felt at the upper end to avoid undue pressure on the peroneal nerve, and with a small felt pad across the dorsum of the foot just proximal to the toes (Figs 900, 901, 902, 903). It is fitted with either walking irons, a plaster-of-paris sole and heel, or a heel fashioned from an incorporated piece of automobile tire.

This fixation as a rule need be maintained for only two or three weeks. During this period the patient may be walking about with the aid of crutches at first and then simply a cane. Following removal of the plaster the patient is given instructions in regard to daily physiotherapy of a very simple type—simple foot and ankle exercises, massages, hot soaks—followed by the application of a snug bandage from toes to

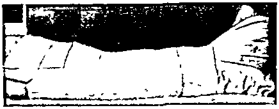


FIG. 899. Temporary pillow splint. Note adhesive strapping instead of safety pins, as advocated by Gurd. However, where displacement in fracture was present originally, the author prefers to use safety pins for snugging up the pillow.

knee Some may be more comfortable with adequate ankle strapping and regain normalcy by walking and simple foot and ankle exercises (In the cases where edema persists the Unna[3] paste bandage may be used

The above describes the usual form of treatment in a large institutional clinic where one cannot rely too much on the intelligence of the patient Such minor ankle fractures in a more selected group can be

FIG 900 (*Top left*) Walking plaster cast Note stockinet and position of circular felt pads about upper end of lower leg and about dorsum of foot (In many cases no stockinet is used)

FIG 901 (*Top right*) Walking plaster cast Cast applied without walking irons

FIG 902 (*Bottom left*) Walking plaster cast Cast applied with walking irons

FIG 903 (*Bottom right*) Walking plaster cast in use

for a short period) Two weeks of this is then followed by a light semi elastic anklet which can be worn for the next two to four weeks and thereafter only on occasions when the patient desires to indulge in some activity more strenuous than walking—e g tennis etc [A leather laced skating ankle brace is excellent for this It has lateral whalebone supports —Ed]

treated even more simply If there is initial soft tissue reaction accompanying the fracture here again use the pillow splint elevation and local icepack for about a day or so before applying the permanent fixation This fixation may be a light low leg castex splint or a light low leg circular plaster of paris In some cases only a snug form of ankle strapping need be applied By the

of the second week the castex or plaster-paris encasement can be removed, and le strapping or a snug ankle corset substituted. Normalcy should be practically attained in such cases in from four to eight eks, depending upon the initial tissue hology, the formation of callus, and the ient's occupational demands

There is a still more simple form of treatment in these unilateral ankle injuries, mulgated by W. G. Campbell[2] of England He believes that minor and major ctures are insufficiently differentiated, l that too often a "minor" ankle fracture fers from treatment which is neither necary nor advantageous. In these "minor" kle fractures he includes the first degree the torsion, abduction, and adduction ctures of the Ashhurst and Brommer ssification. He avers that these minor ctures are essentially stable and require support. He treats such injuries, there-e, very simply.

After clinical and x-ray examination conice him that the injury is unilateral he ects from 10 cc. to 20 cc. of a 2 per cent ocaine solution into the hematoma at the cture site and around the fracture. The in, he states, must be completely abolied, and then the patient is allowed to lk home without support Some swelling d a sense of tightness may be present ter 24 hours but he encourages the pant to walk on his foot. If pain recurs, a cond injection is given. The patient is rmitted to go about his usual daily roule, excepting for a once-a-week check-up, til the x-ray examination reveals good llus formation. However, until more unirsal use of, and results on, this method ve been reported, the author feels that e must regard this local procaine injection eatment as being still in the experimental age, and that it should not be generally ed. One must have fracture judgment that sound and well grounded before he atmpts carrying out such therapy. [In lected cases in intelligent patients in whom disability time is a factor, this procedure is well worth while.—Ed.]

II Injuries Involving Both Sides of Ankle

Next let us consider those ankle fractures which are slightly more complicated, i.e., the injuries involving both sides of the ankle. They include. (1) The fractured external malleolus with complicating ligamentous injury on the inner side of the ankle, (2) the fracture of the internal malleolus, displaced or not, with a ligamentous tear on the outer side of the ankle, or (3) the bimalleolar fracture with little or no displacement (Figs 904, 905, 906). In none of these cases is any diastasis of the inferior tibiofibular joint present.

Because of the local pain and tenderness in these cases the author finds it useful and humane to administer some form of anesthesia (local or general), preferably an intravenous pentothal anesthesia, before doing what reduction and corrective molding there is to do, and before applying the fixation He generally uses low-leg plaster-of-paris fixation of the circular type, with the foot held in a neutral position at right angles, or, as occasion demands (as in cases of fracture of the external malleolus plus ligamentous tear on the mesial side), with the foot at a right angle with moderate inversion. Into this plaster, walking irons of the U type, or a plaster heel, or a piece of auto tire, are incorporated in the proper manner and place Some surgeons prefer a posterior and sugar-tong type of plaster-of-paris fixation, the Stimson[4] splint, or the Delbet[5] plaster splint as advocated by Moorhead and others. [See Chapter 22 for descriptions of splints —Ed.] (If the initial tissue pathology is at all marked in these cases, the fractures are immediately manipulated but are put in a temporary pillow splint (Fig. 899) until the tissue reaction has subsided. Then the snug plaster-of-paris fixation is applied.) This fixation is retained for from two to four weeks, occasionally

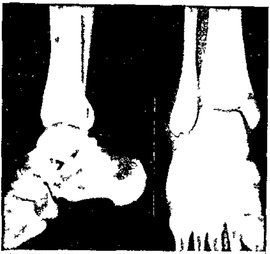


Fig 904 External malleolar fracture of ankle Note there is no displacement Internal lateral ligament was injured

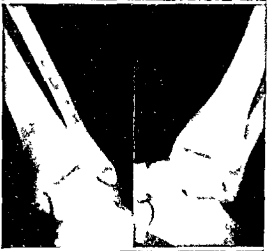


Fig 905 Bimalleolar fracture of ankle Note there is no displacement

Fig 906 Fracture of external malleolus with outward displacement of foot Note widening of ankle mortise

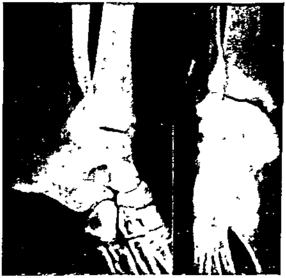


FIG. 907. Fracture of external malleolus with lateral displacement of foot In this case all supporting ligaments were so torn that foot could be easily dislocated in almost any direction

FIG 908 Postreduction of Fig 907 It required pentothal intravenous anesthesia, the application first of a snug posterior plaster shell so as to hold anteroposterior position, and this was followed by application of a regular circular plaster of the high type (midthigh to toes), with some flexion at knee and with foot retained at a neutral right-angle position At end of two weeks this cast was removed and a low walking cast applied. This was retained for five weeks, following which a double-upright ambulatory splint was used This was omitted at end of another five weeks when patient was practically back to normalcy (13 to 14 weeks).

FIG. 909 Bimalleolar fracture with lateral displacement. This required pentothal anesthesia, subsequent reduction, and careful molding of malleoli

longer, when the internal malleolus fails to unite in due time either with good callus or with firm fibrous union The plaster is then generally followed by a protective ambulatory brace for another two to four weeks before allowing full weight bearing

For the cases of fractured external malleoli with accompanying internal ligament injury the author uses a splint with a single outer upright and equipped with an inversion leather cuff at the bottom For the fractured internal malleoli cases with external ankle damage he uses the double upright form of low leg brace These splints need be used only in those cases where there has been some original displacement Otherwise the plaster may be followed by a light castex splinting for two or three weeks or snug repeated ankle strappings with simple physiotherapy given in between strappings The ambulatory splints have the advantages of being protective weight bearing agents and of allowing the patient s foot and ankle to be given massage exercise active and assisted motion and hot soaks These cases should be bacl to a working normalcy (if there is no delayed or non union) in from 6 to 12 weeks the time depending on local conditions and also on the type of the patient s work

Before proceeding to discussion of the next types of ankle fractures the occasional case of bimalleolar fracture with some posterior dislocation of the astragalus but with no associated fracture of the lower posterior tibial margin should be mentioned These cases are reduced under an anesthetic—generally intravenous pentothal—by traction forward thrust of foot manipulation and molding of the malleoli and then put into snug circular plaster of paris extending from the tibial tubercle to the toes The foot is placed in a neutral right angle position The convalescent treatment is then practically the same as described for the preceding type except that it may be more protracted

These cases form a sort of transition type from the so called minor type of ankle fractures to the major type of such fractures

III The More Complicated Fracture Dislocations

Treatment of the more complicated types of ankle fractures the types in which there is displacement of the fracture fragments and displacement of the foot in relation to the tibia—will now be discussed The treatment of these cases particularly must begin as soon after injury as possible Naturally intelligent first aid is of great help But frequently one sees these cases at variable times after injury without any semblance of first aid splinting The earlier the reduction is attempted the easier and better chance there is of accurate replacement of parts Swelling and bleb formation need not be a deterrent factor In such cases —and in fact in many of the cases with impending tissue reaction the author does an immediate reduction treats the blebs etc and puts the leg with the fracture corrected into the pillow splint after the method advocated by Gurd of Montreal (see Fig 899) The anesthesia used in these cases is generally intravenous pentothal occasionally gas ether a low dosage spinal or even scopolamine morphine It is only in the very occasional case that he uses local anesthesia When anesthesia is established the leg and foot are cleaned blebs and abrasions if present are appropriately treated (only very occasionally is it necessary to do joint aspiration) and then the reduction and fixation is done

During the past ten years we have found that the working therapeutic classification of such complicated ankle fractures as laid down by the late F J Cotton has for us at least greatly clarified and simplified the mechanics of reduction and treatment in general of these injuries In fact our residents whose basic training has been in hospitals other than ours and sometimes under men who have developed their own classifications have after a study and applica

tion of Cotton's ideas, always enthusiastically adopted and used his classification. As Cotton[6] has said, it is simply

a working classification, sound in premises, and much more hopeful as to results than the usual routine prescription. The gist of the thing is that it is not the detail of bone lesions that is important so much as the dislocation and displacement—the gross lesion.

an inward shove. The hands are then placed over the malleoli and compressed so as to reposition and mold them to restore the ankle mortise. The foot is kept at right angles and in moderate inversion and the knee at about 25° flexion.

FIXATION IN CASES WITH NO MARKED TISSUE REACTION In these cases the author

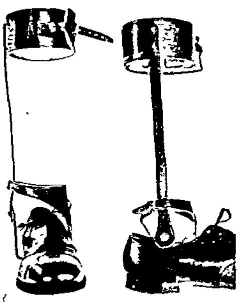


FIG. 910. Convalescent ambulatory splint. This is the type of ambulatory splint used in convalescent care of so-called Pott's fractures (Cotton's Class I). Note outer upright iron and inversion leather cuff to go about ankle.

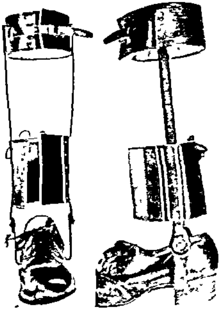


FIG. 911 Convalescent ambulatory splint This is used in aftercare of ankle fractures other than so-called true Pott's fractures

F. J COTTON'S CLASSIFICATION

Class I. This class is the outward displacement of the foot with malleolar fracture (our general interpretation of Pott's fracture) (Figs 907, 908, 909).

Reduction. With the patient under anesthesia, the knee is well flexed, the lower leg is held by an assistant, and the foot is grasped by the surgeon with one hand about the heel and with the other about the foot proper. Increasing rhythmic traction (no forceful initial yank!) is applied, and the foot is thrust or pushed into position by

applies the circular type of plaster-of-paris fixation extending from high midthigh to the toes, maintaining the knee at about 25° flexion and the foot at right angles and in moderate inversion. While the plaster is hardening the hands should be used to keep the malleoli snugly in place in order to regain and maintain the normal ankle-joint mortise. The underlying padding in such cases consists generally of a stockinet plus one or two thicknesses of sheet wadding This plaster is retained for two or sometimes three weeks, and then a snug-fitting

low (to the knee) circular plaster with no padding (skin tight plaster) is applied with the foot still kept at right angles and in moderate inversion The patient is not generally up and about (on crutches) until this low plaster is applied It is bivalved in another two or three weeks the leg taken out carefully once a day and light massage and gentle active and assisted active motion begun

At the end of the seventh to eighth week of fixation the plaster as a rule is removed and an ambulatory low leg splint with a single outer steel upright and inversion cuff about the ankle is applied (Figs 910 911) Also in many cases the patient s shoe is fitted with a special leather inner sole with plantar and anterior arch pockets for appropriate felt padding and with a 1/6 to ¼ inch Thomas heel The protective weight bearing splint is generally worn for from four to eight weeks depending on the case—its original injury extent the local callus formation and the patient s cooperation (This latter often means everything in arriving at a good end result)

During this period simple but persistent daily physiotherapy is in order i e massage active and assisted active motions of foot and ankle a definite series of weak foot and ankle exercises hot soaks and hot whirlpool baths if accessible In addition to these local exercises the patient should also go through daily simple setting up exercises including the hip thigh and knees If there is troublesome local edema present after removal of the plaster the author often applies a snug Unna paste stocking for ten days or so (this is removed once during this time in order to give some physiotherapy and is then re applied) and then return to the daily routine as laid down originally About the end of the twelfth week the convalescent splint is removed but the patient is still kept on his daily routine of physiotherapy massage and exercises The disability period in these cases is generally for from 12 to 16 weeks

This convalescent treatment is modified in some of the cases where no diastasis was originally present In these cases a snug walking plaster of paris is applied at about the end of the second or third week and is continued at the end of the eighth week (on the average) (see Figs 900 to 903) Then the convalescent splint is applied as in the other cases

Fixation in Those Cases with Marked or Impending Tissue Reaction In these cases the reduction should be carried out as in other cases but the fixation should be of the pillow type after the method of Gurd[7] This procedure is best described by Gurd

> For this purpose a moderately large deep feather pillow is required covered with a pillow slip made of strong material The leg is placed upon the centre of the pillow with the latter projecting almost six inches beyond the heel The pillow is made to encircle the leg commencing about or better above the knee and firmly secured under tension by means of safety pins passed in the long axis of the limb Working from above downward toward the ankle joint safety pins are placed in this way at short intervals In this manner lateral and circular compression is exerted this is of value in limiting oedematous swelling and of forcing by gradual pressure if reduction has been incomplete displaced bones into position Particularly is this useful in overcoming diastasis of the fibula from the tibia The projecting part of the pillow below the foot is folded over the sole in such a way that the foot is forced into as marked dorsiflexion as possible and in such a manner that abduction or adduction is induced as required It [the splint] must be readjusted several times during the first two or three days The limb is allowed to remain in the pillow for a variable number of days the length of time dependent upon several factors more especially the severity of the injury and amount of swelling present

In the cases in which we have used this pillow splint it has been followed by a snug fitting circular plaster of paris of the type used following the original high encasements applied as initial fixation in the cases described above The subsequent treat

ment follows along the same lines as there given.

Before proceeding further, we would like to say here that since we have been using protective convalescent splints following the omission of the plaster fixation in these ankle fractures we have had no recurring deformity (e.g. valgus deformity). We know, from unfortunate experience, that too early and unguarded direct weight-bearing in these cases is fraught with danger and leads to foot and ankle deformities, even though the initial reduction and fixation of the fracture had been well executed. These are the cases which are likely to be undertreated.

[The author's distinction between fractures of the first two groups and those of the third group is a sound and notable one. The reason for the prolonged treatment period in the latter is the diastasis of the inferior tibiofibular joint. The torn ligaments heal by the growth of thin and elastic new connective tissue. It takes time and functional stress to transform this tissue into a dense ligamentous structure which will not stretch under functional strain Any stretching will again widen the mortise and render the ankle unstable. Hence the protracted period during which the tibia and fibula must be held tightly together, and the delayed and long-protected weight-bearing. —Ed.]

Class II. This class consists of those cases in which there is an inward dislocation of the foot with malleolar fracture (inversion type of fracture). The author has found cases of this kind to be quite infrequent (Figs. 912, 913).

Here, as in other fractures, early reduction and fixation is essential. As a rule, pentothal anesthesia is the author's anesthetic of choice. Other forms of anesthesia may be used according to the surgeon's preference. The displacement is reduced by steady traction with outward pressure on the foot, followed by careful molding of the malleolar fractures as described above. The foot is kept at right angles and in neutral position.

FIXATION. The fixation choices are: (1)

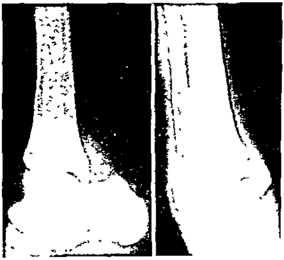


FIG 912. (*Left*) Bimalleolar fracture of ankle with inward displacement of foot. Lateral view.

FIG. 913. (*Right*) Same as Fig. 912. Anteroposterior view This is a very infrequent fracture

FIG. 914. Bimalleolar fracture of ankle *with fracture through lower posterior* margin of tibia plus a posterolateral dislocation of foot Shows prominent lower end of tibia and foot in abnormal posterolateral malplacement Note local swelling about inner side of this ankle. This case had an original emergency pillow splinting which kept ankle in such good condition that our initial post-reduction was a snug plaster-of-paris cast.

Pillow splint (Gurd[7] type) where there is much tissue reaction This, of course, to be followed as soon as deemed safe by the more permanent types of fixation. (2) Circular plaster of paris extending from the

FIG 915 X ray film of Fig 914 (prereduction) lateral view Note how far back lower end of tibia is on astragalus—or rather *off astragalus*

FIG 916 X ray film of Fig 914 This view of ankle well illustrates outward thrust of foot in such a fracture

FIG 917 (*Left*) X ray film of Fig 914 (postreduction) anteroposterior view Shows reduction of fracture shown in Figs 915 and 916 Note how snug ankle mortise is Transverse fracture of internal malleolus shows a little gap In this case it meant prolonging *fixation time to ten weeks and delaying ulti* mate return to normalcy (five months in this case)

FIG 918 (*Right*) X ray film of Fig 914 (post reduction) lateral view Shows good replacement of fractures and dislocation

tibial tubercle to the toes (3) Sugartong and posterior molded plaster extending from the knee to the toes (4) The Stimson *type of plaster fixation or a posterior plas* ter shell with a lateral plaster of paris slab

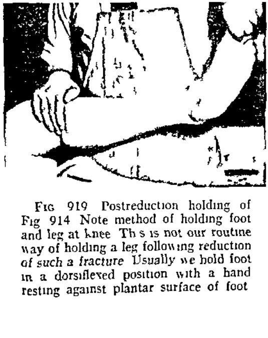


FIG 919 Postreduction holding of Fig 914 Note method of holding foot and leg at knee This is not our routine way of holding a leg following reduction *of such a fracture* Usually we hold foot in a dorsiflexed position with a hand resting against plantar surface of foot

Fixation in all these cases is maintained for about six weeks on the average (occasionally longer) If in the surgeon's judgment the case is one *suited for a walking plaster* it is applied after two weeks fixation by the initial encasement If the initial encasement is used throughout it is bivalved about the fourth week and the leg is removed daily for massage active and assisted active motions and local heat and then replaced in the bivalved plaster which is snugly bound up with strap or bandage

In either case at the end of the sixth week (sometimes later) the plaster of paris fixation is removed and the leg goes into a low leg ambulatory splint which is of the double upright type which will allow protected weight bearing This leg brace should be used generally for another three to five weeks and then gradually discarded Thus the average treatment period ranges between 10 to 12 weeks Delayed or nonunion of the internal malleolar fracture may cause prolongation of this period Here again in

many cases a custom-made leather inner sole with a plantar pocket for felt-pad inserts may be used. Also, if the foot has a tendency to varus a reversed Thomas heel (1/6 inch) is indicated. (See Fig. 911.)

Class III. In this class, Cotton places those cases in which there is a posterior (or posterolateral) displacement of the foot with a bimalleolar fracture, plus a fracture of the lower posterior tibial articular surface (Figs. 914-922). In order to obtain anatomic reposition in these cases by the closed manipulative method it is paramount that treatment be instituted at once The type of anesthesia which the author likes best in this instance is a low-dosage spinal anesthesia because it gives better muscle relaxation than any other form of anesthesia. However, if preferred, or if spinal anesthesia is contraindicated, any other form of anesthesia, including local, may be used. Again, local acute tissue pathology is no contraindication to immediate reduction

With the patient under anesthesia the surgeon grasps the foot with his two hands, one about the heel and the other about the dorsum of the foot, and exerts rhythmic increasing traction on the plantar flexed foot (counter-traction being obtained generally by an assistant holding the leg above the ankle and with leg well flexed at the knee) With this traction maintained, the surgeon rocks the foot into dorsiflexion while, at the same time, the assistant exerts sudden dorsalward pressure on the lower end of the tibia. This maneuver will generally reduce the displacement of the foot, and if the x-ray examination has previously revealed that the tibial fragment is narrow at its posterior-joint end, this dorsiflexion will generally lock the foot and retain that fragment in place. However, if the lower end of the tibial fragment is so wide as to appose some of the astragalar articular surface, it will be found that, after the displacement has been reduced, the posterior fracture fragment is best retained in position by putting the foot in about 100 to 110° plantar flexion. This point has been driven home to the author by open reductions and fixations on such cases Following this step the malleoli are carefully molded, special attention being paid to the lower tibiofibular articulation

FIG. 920 Fixation following reduction of Fig. 914. In this figure note length of cast, flexion at knee and position of foot This was the initial fixation in this case

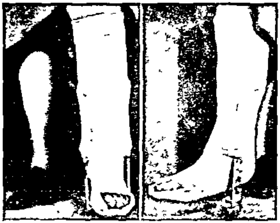


FIG. 921. (*Left*) Second cast of case shown in Fig 914

FIG. 922. (*Right*) depicts walking cast applied to case shown in Fig 914, three weeks following application of cast shown in Fig. 920 Note edge of felt padding showing at upper end of cast and also just proximal to toes.

to be certain that the normal ankle mortise is regained (Figs 923, 924).

[In reducing this fragment of the posterior articular portion of the inferior tibia it is important to keep the knee well flexed. Similarly, reduction is difficult, if not impossible, to maintain with the knee straight. For this reason it is felt by many that the

knee flexion in immobilization for the first three weeks should be 50 to 60° i e with the knee at an angle of 120 to 130° The lessening of tension on the calf muscles attached through the tendo achillis is of course the purpose of flexion at the knee —Ed]

FIXATION For fixation a circular plaster of paris is applied It extends from mid thigh to the toes the knee being in 25 to 30° flexion [See editorial note preceding this paragraph] Here again if the surgeon prefers he can use the sugar tong and posterior molded plaster of paris splint fixation or the Stimson type However the author has found the circular type of plaster more nearly foolproof Of course where the tissue reaction is severe the Gurd pillow splint fixation should be used first and the leg placed in an appropriate support of the Braun type This pillow splint is replaced as soon as deemed safe by the regular high plaster of paris It is well to have a check up x ray examination made in such a case just before the pillow splint is removed so as to be certain that no slipping away from the initial reposition has taken place If a change of position is noted in this x ray the case should be given pentothal intravenously the pillow removed the malposition corrected and the usual high plaster applied

FIG 923 (*Left*) X ray views of another of this type of fracture of the ankle (Cotton s Type III) Note widened ankle mortise
FIG 924 (*Right*) Postreduction films of case shown in Fig 923 These show reposition with a snug ankle mortise

Anatomic reposition of the posterior marginal tibial fragment is essential If this fracture is of any real width at its base the articular end and is displaced an eighth of an inch or more from the articular surface it is quite likely if not reduced to become the cause of subsequent persistent pain in the ankle on weight bearing Such an end condition generally requires an ankle joint fusion So if good reduction is not obtained and the patient s general condition warrants it an open operation with reduction and internal fixation by screw is in order (Figs 925 927)

In ankle cases of this type which come late to the surgeon for treatment and where the attempt made at reduction has been unsuccessful continued traction should be used This is best obtained by Kirschner wire traction through the os calcis with the foot held more or less in plantar flexion and the leg placed on a Braun splint This is kept up for ten days or so and then under a general anesthetic an attempt is made to reduce the fracture If this reduction is good the usual plaster fixation can then be

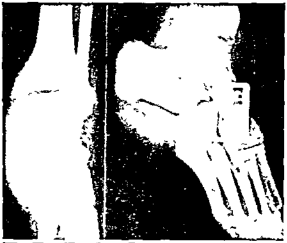


FIG. 925. Bimalleolar fracture of ankle with fracture through posterior lower lip of tibia and a posterior dislocation of foot. In this case note comparatively wide base (joint end) of posterior tibial fragment.

FIG. 926. Postreduction plate of Fig 925 Shows an unsuccessful attempt at reduction. Posterior lower tibial fragment was not reduced and if left in that position would, in our opinion, have caused a painful and crippling tibio-astragalar joint, so open operation and internal reduction and fixation were decided upon.

FIG 927 Postoperative films of Fig. 925 Note position of nail and smooth tibio-astragalar joint line. Reduction and fixation were done through a posterolateral approach to lower end of tibia

applied Such a procedure may save a case from an open reduction

The convalescent care of cases that have been successfully reduced and put in plaster fixation is extremely important If this fixation is removed too early the initial reposition may be lost So in these fractures the high plaster is retained intact for from two to three weeks and then it is carefully replaced by a snug fitting plaster to the knee We do not like these to be of the walking type since it has been our experience that these injuries even with snug fitting plaster may show some recurrent displacement if such protective weight bearing is allowed As a rule the low plaster is bivalved at about the end of the fourth or fifth week and carefully directed and intelligent physiotherapy is begun This is done in the same manner as previously described From the end of the seventh to the tenth week all plaster is removed It is immediately replaced by a form fitted low leg ambulatory splint of the double upright type with a special protective leather cuff over the lower end of the tibia (See Fig 911) This brace is removed only to allow for the daily massage foot and ankle exercises and hot soaks or the hot whirlpool bath if accessible It is worn for the next six to eight weeks Then it is advisable for the patient to use a well fitting mesh or laced leather ankle support when taking long walks or later when playing tennis dancing etc The disability period in these cases is usually quite protracted 14 to 18 weeks is a fair estimate

Those fractures of this type in which an open reduction and internal fixation by nails or screws is done have a shorter disability period and the after care is much simpler With the posterior fragment held snugly in place by screws the malleolar fractures well molded or also retained by screws and any diastasis corrected and the lower ends of the tibia and fibula held snug by means of a screw the plaster fixation need be only a simple light circular plaster or merely a well fitted posterior plaster of paris shell

When the wound is healed and the sutures are out active and assisted active motion can be instituted The simple fixation can be omitted at the end of the fourth

Fig 928 (*Left*) Comminuted fracture of lower end of tibia (Cotton s Class IV) Note upward thrust of foot and disturbance of ankle mortise

Fig 929 (*Right*) Comminuted fracture of lower end of tibia plus fracture of fibula This case was not amenable to ordinary closed reduction methods nor adaptable to efficient open work because of the multiple comminution Hence it was treated by Kirschner wire traction

or fifth week and the convalescent splint as just described used in its place for another four weeks or so. In other words, if no post-operative complications are encountered, the disability time in this kind of complicated ankle fracture-dislocation is about cut in two. This warning, however, should be given here: the open reductions and internal fixations of such fractures should be left to the hands of surgeons well accustomed to and experienced in such procedures. They should not be done by the surgeon who sees only the occasional fracture case. [See discussion of open reduction, Chapter 22.—Ed.]

Class IV. This class consists of those ankle fracture-dislocations in which there is an upward displacement of the foot with a resulting comminuted fracture of the lower end of the tibia. Ankle injuries of this type are real problems and give the greatest trouble due to the large number of poor end-results (Figs. 928-931).

The conservative treatment of these ankle fractures may be carried on in two ways:

1. Under general anesthesia, preferably of the low-dosage spinal type, sustained skeletal traction by means of a Kirschner wire through the os calcis is followed by local manipulation and molding of the fragments, by hand or by a redresseur. This is best done with the aid of the fluoroscope. If adequate reposition is accomplished, then a circular plaster of paris is carefully applied, the wire traction being maintained during its application. The foot is ordinarily kept at right angles. In some cases, it is found that reposition of fragments is best retained by the foot in plantar flexion and the wire is then passed through the anterior part of the os calcis. The wire and holder are incorporated in the plaster. The traction is released only when the plaster has set. The encasement should extend from the mid-thigh to the toes with the knee kept well in flexion.

Unfortunately, relatively few of these fractures are amenable to successful treatment by this method. However, if successful, this fixation is maintained for from three to four weeks and then a low, knee-high, snug plaster is applied. This is bivalved in another two weeks or so, and

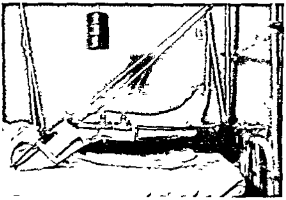


FIG. 930. Fig. 929 in traction. Shows Fig. 929 in plaster cast and in os calcis Kirschner wire traction, on a Thomas splint with Pearson flexion attachment. This cast was applied after several days' traction on a Braun frame and it was so applied that there would be no interference with continued traction but allowed maintenance of local malleolar molding and prevented rotation of foot. This was maintained for a little over three weeks and then a low snug cast was applied.

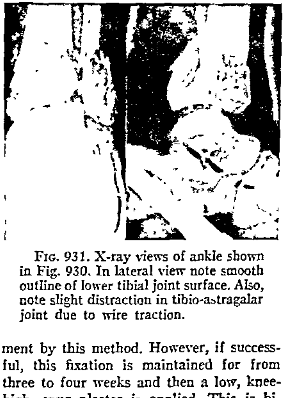


FIG. 931. X-ray views of ankle shown in Fig. 930. In lateral view note smooth outline of lower tibial joint surface. Also, note slight distraction in tibio-astragalar joint due to wire traction.

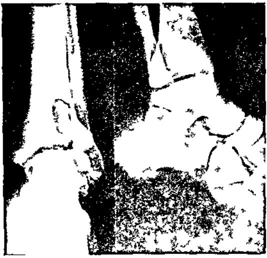


Fig 932 Comminuted fracture of lower end of tibia (right ankle) No reduction required in this case because of no displacement of fragments Treated by simple well molded plaster of paris cast fixation

Fig 933 Comminuted fracture of lower end of tibia (left ankle) Shows an x ray of left foot of same case as Fig 932 Here a closed attempt at reduction was unsuccessful and so open reduction and fixation were done

Fig 934 X ray views of Fig 933 after open reduction and fixation by means of screws Note It would have been well in this case to have added a snugging transfixion screw through lower end of tibia and fibula

massage, passive and assisted active motion, and local heat are given daily. Following two or three weeks of this the plaster (about the eighth to tenth week) is removed entirely. In its place, a low-leg ambulatory splint similar to that used in the preceding type of fractures is used. Walking, daily foot and ankle exercises, and heat are now the order of the day. The convalescent brace is retained for from four to six weeks, making the entire treatment period from three to four months' duration. But, as has been said, only a few of these cases can be successfully treated in this manner.

2. The greater number of these particular ankle injuries are treated by continued Kirschner wire traction through the os calcis with repeated molding of the fragments. This traction is maintained for about three to four weeks and then a circular plaster-of-paris is applied with the foot kept at right angles, traction being maintained while the plaster sets. The treatment from here on is the same as with method 1.

The author prefers open operation, reduction, and internal screw fixation in these fractures because of the large percentage of poor end-results in them. But early good operative work is practically impossible in many of them because of the attendant multiple comminution. Early operation on these fractures is comparable in difficulty in many instances with that met in operative work on fresh os calcis fractures. Those cases in which the comminution is limited and the bone fragments of fair and concrete size, if closed manipulation plus traction does not give reposition, are favorable ones for open operation. If this can be done the convalescent time is shortened and a good end-result may ensue (Figs. 932-934). [For the use of the various forms of pin-distraction apparatus, including the Haynes, Stader, and Roger Anderson apparatuses, see Chapter 22.—Ed.]

During the convalescent weight-bearing stage of these injuries frequent and careful observations, clinically and by x-ray, must be made. If the patient is found to have more or less persistent pain in the tibio-astragalar joint area on walking, and if that pain seems to increase as time goes on, then a tibio-astragalar arthrodesis is in order. It will be found that such a fusion has to be done in many of these cases in order to give the patient a painless-functioning lower extremity. If the fusion is successful with the foot in a good weight-bearing position, there should be no real ensuing disability. [See ankle-joint fusion, Chapters 7 and 15.—Ed.]

Fractures of Foot

The treatment of fractures of the foot is a most serious proposition. Good end-results in displaced fractures of the astragalus, cuboid, scaphoid, and os calcis are difficult to attain. Even after more than 20 years of more or less concentrated work on the os calcis, the author has found himself pushed to attain even 75 to 80 per cent good end-results in those os calcis fractures of the "smashed" type (comminuted fractures into the subastragalar joint). Too often, following foot fractures, one sees feet painful on walking, with crippling joint pains, contractures, local deformities, and painful traumatic flatfoot, or with a disabling heel or a toe-drop position. From an economic standpoint, poor or even fair end-results in such injuries are disastrous to men requiring skilled footwork, such as "pole-men" in the telephone and telegraph companies, structural-steel workers, roofers, painters, and professional athletes. It is important that every so-called "foot sprain" should be given a careful x-ray examination before it is diagnosed as negative in regard to fracture or dislocation. Before proceeding with the treatment proper of these tarsal and other fractures, see Figs. 935-937 for a fair anatomic picture of the foot.

FRACTURE OF ASTRAGALUS

Before discussing the treatment of these fractures it should be noted (Holmes and

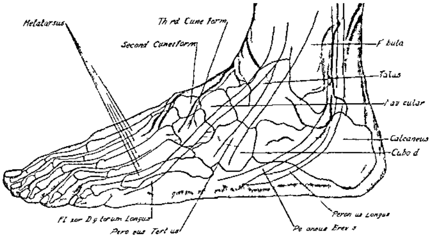
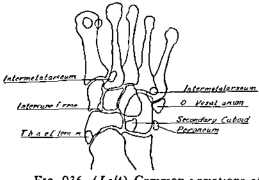


FIG 935 Sagittal section of ankle and foot Drawing of a specimen taken from Tufts Medical School Unfortunately all the metatarsals are not seen It gives a fair picture of the various joints—tibio-astragalar calcaneo astragalar etc —and of the various tarsal bones and their relationship to each other In this section one gets a clearer conception of the so called angle of incidence formed by a line drawn parallel to posterior calcaneo astragalar joint and one drawn parallel to upper posterior surface of os calcis In viewing such a section it makes one wonder why there is no greater foot disability following excision of some of the tarsal bones than there is as for example the astragalus or scaphoid in irreducible fractures



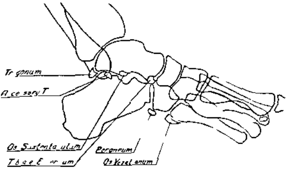


FIG 936 (*Left*) Common variations of tarsus Anteroposterior view

FIG 937 (*Right*) Common variations of tarsus Lateral view It is quite important to have in mind Fig 936 as well as this figure when scanning x ray views of the feet where fractures are questioned Os trigonum is quite often mistaken for a fracture of astragalus Here is what Holmes and Ruggles say on this

The astragalus bears a backward prolongation of variable length which often exists as a separate bone, the trigonum, and when present it must be differentiated from a fracture of a long process The next in order of importance is the tibiale externum a small detached bone which sometimes occurs at the posterior end of the scaphoid on the inner side of the foot

'The small separate center of ossification on the outer side of the posterior end of the fifth metatarsal may persist into adult life as a small bone called the vesalianum

Divided sesamoids in the tendons of the flexor brevis hallucis beneath the head of the first metatarsal are fairly common They must be carefully differentiated from fractures of single sesamoids, which are extremely rare'

Ruggles[3]) that "the astragalus bears a backward prolongation of variable length which often exists as a separate bone, the trigonum, and when present it must be differentiated from a fracture of a long process" *(Fig. 938)*.

In fractures of the astragalus where there is only an oblique fracture of the neck with no displacement, the initial treatment consists of a circular low-leg plaster-of-paris fixation, with the foot in the medial position, the cast being well molded, especially in the submalleolar and foot-arch areas. This splinting is retained for six or seven weeks. Its removal is followed by two weeks of daily physiotherapy consisting of massage, active and assisted active foot and ankle motions, increasing toe and foot exercises of a non-weight-bearing type, and local heat. A snug linen mesh bandage should be applied betweentimes This local physiotherapy should regain considerable of the lost muscular and ligamentous strength so *that the patient then* can begin to do gradual increasing weight-bearing. As an aid to the patient's foot comfort and convalescence a leather inner sole with a pocket for felt arch pads is fitted to the shoe In such uncomplicated astragalar fractures a return to normalcy may be attained from the twelfth week and on.

If, however, this fracture runs obliquely from the neck back through the body with the anterior fragment depressed and the posterior one displaced backward and even rotated, or if the fracture is transverse and the fragments displaced, the initial treatment is more complex. The patient will require a general anesthetic, and the reduction should be done with fluoroscopic aid, if possible.

First, manual traction of the foot with local manipulation is tried. If unsuccessful, then, following preliminary traction by means of a Kirschner wire through the os calcis, the foot is placed on a wooden wedge, and with the foot in marked plantar flexion traction is exerted on the toes. If this, with local manipulation, is successful in repositioning the fracture, a circular low-leg plaster of paris is applied as in the case of the

FIG 938 Os trigonum of astragalus Note how easy it would be to make a fracture diagnosis here.

FIG. 939. Fracture of astragalus Note fracture through neck of astragalus with *dislocation of head. Ultimately it re*quired an open reduction.

simple fracture, with the foot in neutral position. This fixation is replaced by another snug one of the same type in about two weeks. Fixation in these cases is main-

FIG 940 Fracture of astragalus This shows case of Fig 939 following operative reduction It is in plaster cast fixation Note that fracture line is barely visible

tained about eight weeks — occasionally somewhat longer depending on x ray check up —and then the same convalescent treatment is given as already described

When good reposition cannot be obtained by this closed method an open operation is in order It is quite important to have these fractures properly reduced In such operations the removal of any portion of the astragalus should be avoided since such a procedure results in a high degree of permanent disability The author has noted in one instance where open operative work had been done in a tarsal fracture of the fracture dislocation type that some type of degenerative osteitis had set in (Figs 939 941)

This may have been due to the added trauma to the local circulation It gave a painful foot It is because of such a complicating possibility that the author likes to institute early physiotherapy especially heat in these operative cases with of course late weight bearing Therefore absolute fixation is maintained in these cases for four weeks and then a new snug plaster is applied This is bivalved as soon as it is dry, and physiotherapy is begun Weight bearing however is not begun until about the eighth to tenth week When it is found after two or three months of actual use and weight bearing that the patient has persistent pain on walking a tibio astragalar fusion must be considered Astragalectomy should be done only as a last resort

FRACTURE OF TARSAL SCAPHOID

Fracture of the tarsal scaphoid (Fig 942) is quite a rare fracture Like the carpal scaphoid it may go unrecognized For that reason careful x rays must be taken of all severe foot and ankle injuries particularly so-called foot sprains Also these x rays


FIG 941 (*Left*) Fracture of astragalus This x ray film was taken 14 weeks following operation on case in Fig 939 Astragalus appears dead Patient has considerable pain with it on slightest weight bearing Astragalectomy or fusion is being considered in this case

FIG 942 (*Right*) Fracture of tarsal scaphoid

must be interpreted intelligently because of the supernumerary and sesamoid bones which may confuse the reading. Since this tarsal bone is a sort of keystone in the longitudinal arch it is important that the fracture be well reduced. [See also Sprain

Fig 943 Fracture of cuboid

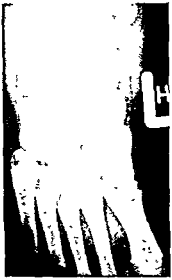


Fig. 944 Fracture of cuboid.

and Sprain Fractures, in Chapter 41.—Ed.]

If the fracture is a simple one without displacement, then a snug plaster-of-paris boot is applied and retained for a six-week period. This is followed by a snug linen mesh bandage and two weeks of daily physiotherapy as previously outlined in the treatment of astragalar fractures. Weight-bearing is then begun but some well-fitting arch support preferably of the leather inner sole type should be worn for several months.

In the more complicated types where the scaphoid is comminuted the patient will have to be initially treated under a general anesthesia. If ordinary closed reduction by traction and manipulation is successful the procedure as just outlined is followed. But open operative repositioning is in most cases the only choice If such reduction is found impossible the widely separated fragments should be removed or even the entire bone may be excised The gap left by the

Fig. 945. Bilateral os calcis fracture. Man in this case fell 15 feet. (See Figs. 953 to 956, inclusive, for x-ray pictures)

scaphoid removal may be partly obliterated by a bone graft. Crossan[10] believes a good result is obtained with or without a bone graft. The fixation following this procedure is of the same type as that used in the closed method, but is retained for about eight weeks and then, after a preliminary physiotherapy of several weeks, gradual weight-bearing is allowed with a molded steel plate being worn for six weeks and this followed by the leather inner sole type of foot support for another two months or so

FRACTURE OF CUBOID

Fracture of the cuboid (Figs. 943, 944) is also a rare type of fracture and, fortu-

nately, the usual one has very little displacement The treatment consists of splinting by a snug well molded plaster of paris boot This is removed in about six or seven weeks and then the routine after care as outlined above is carried out When there is a displacement or dislocation operative reduction under a general anesthetic must be done Here again it must be remembered that it is quite important to institute early physiotherapy especially heat in order to stimulate the local circulation as much as possible And of course comparatively late direct weight bearing (eighth week and on) is also in order

CUNEIFORM FRACTURES

Isolated cuneiform fractures are rare They are most often seen in combination with metatarsal and other tarsal fractures The treatment consists in a plaster of paris boot with the foot at right angles the heel held in varus and the anterior part of the foot in slight pronation This fixation is retained for from four to six weeks and then the usual physiotherapy routine as described is followed

FRACTURE OF OS CALCIS

The most common variety of fracture of the os calcis is that in which there is a rather formless comminution of the bone as a whole—the bone is broken through in nearly a vertical plane just in front of or commonly through the posterior articular surface between it and the astragalus with a lateral broadening (piling up) and a pushing up of the posterior part of the heel The latter displacement decreases or obliterates the so called angle of incidence These are most difficult cases to treat and in which to obtain painless functioning heels and feet

At the Boston City Hospital we have found that a conservative method evolved by us through the years since our late chief Dr F J Cotton first formulated a molding and fixation method for these fractures gives us a fair percentage of good end results By good end results we mean painless functioning heels and feet within a four and one half to six month period the patients returning to their original occupations Some of the remaining cases (roughly 15 per cent) obtain a similar result in about a 16 to 18 month period In the remainder (about 10 per cent) we find that some type of operative procedure has to be done in order to give a painless heel Incidentally we have found that operatively arthrodesed cases who were originally working as structural steel men telegraph pole men roofers and so forth cannot take up such work again without risk to themselves They seem to have lost too much of the fine balancing power and springiness of the foot (Fig 945)

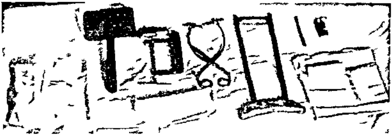


Fig 946 Boston City Hospital os calcis fracture operating kit A rolled sterile towel a weighted seven pound wooden mallet a scalpel the sawed off upper end of a crutch tongs Forrester clamp a sterile covered sandbag (Courtesy Hermann O J Jour Bone and Joint Surg 19 710)

FIG. 947. Disimpaction of fracture of os calcis by mallet. Patient turned on side opposite injury. Sandbag is placed beneath external malleolus. Then, with solid heavy blows, impaction is broken up and piled-up *bone beneath external malleous pounded* down.

FIG. 948. Manual molding after disimpaction. Illustrates how easily thumb can be pressed into depression beneath external malleolus and how heel can be molded by fingers after pounding

FIG. 949 "Pulling down" os calcis With a scalpel, small incisions are made about an inch or so above apex of heel Tongs are driven in and locked, and traction is then made in a rotary fashion, beginning downward and swinging upward, with counter-traction exerted just proximal to cuboid joint

FIG 950 Remolding of os calcis by bone clamp. Os calcis is remolded systematically from external malleolus downward by means of Forrester clamp. Again, traction is exerted downward and upward with counterpressure in os calcis and cuboid areas.

FIG. 951. Dressing and placing of submalleolar pads. Small sterile dressings are first placed in the two stab wounds in heel, and then on dressings is superimposed a snug roll of felt, four by one and one-quarter inches, placed horizontally beneath each malleolus.

The treatment about to be described is one which has been evolved during the last 20 odd years at the Boston City Hospital

Preliminary Treatment (Quoted from Author's Article[11])

1 Roentgenograms are made upon admission a lateral and an axial view of both heels being taken The films of the uninjured heel are used as a comparison for measurements of the injured one and also to detect any bone

Fig 952 Finished fixation cast A low plaster of paris cast is finally applied with foot somewhat inverted and in plantar flexion While this cast is hardening pressure is brought to bear over pads

anomalies that might complicate the interpretation of the fracture The axial view is made as follows A strip of two inch roller bandage is placed in a loop about the anterior arch of the foot with the ends held by the patient the foot is drawn into moderate dorsiflexion the film is placed underneath the heel and the lower leg and finally, the axis of the x ray tube is directed onto the plantar surface of the heel at an angle of 45° In severe cases a third view is taken in an effort to see more clearly the subastragalar joint Since compression fractures of the lower spine occur not infrequently with os calcis fractures (in about 10 per cent of our cases) routine lateral and anteroposterior roentgenograms of the lower thoracic and lumbar vertebrae are made to rule out such fractures This procedure has been adopted by us so that no such lesion will be inadvertently overlooked There have been patients with fracture of the os calcis complicated by spine fracture who did not complain of any back discomfort Therefore such a roentgenographic check up of the spine is now the rule in our first examination From the roentgenograms of the os calcis the surgeon learns the exact amount of lateral expansion the comminution present the condition of the astragalocalcaneal joint the salient angle or angle of incidence the location of the vertical and longitudinal fracture lines (one must plot these lines so as to avoid them in the placing of ice tongs during reduction) the condition of the sustentaculum tali and finally the existence or nonexistence of subluxations between the os calcis and the cuboid or between the astragalus and the scaphoid

2 The emergency treatment is very simple —the foot and lower leg are encased comfortably in a pillow and sides splint with appropriate bleb dressings and an icebag if deemed necessary

3 A one or two day bone prep is given as soon as the acute local reaction has subsided which may be from one to ten days

Reduction and Fixation

1 The operating kit consists of a tightly rolled sterile towel a sandbag with a sterile cover a seven pound large wooden mallet a pair of bone tongs the Forrester bone clamp a sawed off crutch a scalpel a sterile dressing and two rolled pieces of felt bound by adhesive (four inches by one and one fourth inches) [Fig 946]

Besides this kit there are the usual sheet wadding and plaster of paris bandages

2 Local anesthesia is never used Generally a light dosage low spinal anesthesia or a gas ether anesthesia is employed

3 The technic is as follows The patient is turned on the side opposite the injury and a sandbag is placed under the inner side of the heel The snugly rolled towel is placed beneath the external malleolus and then with solid heavy blows the heaped up bone beneath the external malleolus is pounded down until the normal depression beneath the external malleolus is restored [See Fig 947] Roughly, we gauge it by placing the thumb

in this depression, and if the thumbnail is on a level with the outer surface of the external malleolus, we are satisfied. This procedure we have named "disimpaction." Offhand it would seem that such heavy pounding would cause terrific bruising of the tissue, with resulting necrosis. This is not so. In only one case did we get any degree of pressure necrosis and that was in a case in which we did not wait until all the acute local traumatic reaction (swelling, etc.) had subsided and in which there was insufficient padding. We believe the tightly rolled towel with the broad-faced mallet precludes such damage.

The heel is quickly molded by hand [Fig. 948], and the various motions are tested. The testing of motions, particularly the lateral, is important. It has been pointed out that by doing this we may lose our reduction in part or in whole. If we do not test, we will not know whether there still exists a submalleolar bone block, and whatever is lost at this stage in the reduction is regained immediately by the traction and remolding. With the scalpel, small stab wounds are then made in the upper posterior part of the heel (care being taken that no fracture lines are entered, these having been previously located by x-ray). The tongs are driven in and locked, and with countertraction from the crutch, which has its handle resting against the operator's abdomen or chest and the cross-bar of the sawed-off end resting against the sole of the foot in the line of the calcaneocuboid and the astragaloscaphoid joints, lusty traction is made in an arcwise fashion [Fig. 949]. This pull begins in a downward and outward direction and, with well-sustained traction, it is carried upward and toward the operator. This type of pull was adopted to overcome the posterior vertical pull of the calf muscles through the tendo achillis and the inferior horizontal pull by the intrinsic muscles of the foot. It is here that the value of the preliminary disimpaction is felt—the large posterior fragment can be pulled down, whereas, if it were left impacted, only a long-continued traction could do this

FIG. 953. (*Left*) Lateral x-ray view of right os calcis of case shown in Fig 945 Note comminution extending into subastragalar joint. (Prereduction.)

(*Center*) Lateral view of subject in left-hand illustration above, after reduction and in a cast.

(*Right*) Lateral view of left-hand illustration, 15 months later

Patient, J. J., a painter, dropped 15 feet from a ladder, striking on both heels. Os calcis was molded and put in fixation and patient given routine treatment He was back at part-time work in five months and at full-time work in six months. There was absolutely no loss of motion, nor any local complaint of pain, especially in regard to the involved joints.

The tongs are now removed and the heel is remolded by the use of the bone clamp fitted with special submalleolar aluminum pads as devised by the author [Fig. 950]. When the desired compression has been obtained by this clamp, the traction is again applied through the clamp. The entire heel is carefully and systematically molded in this fashion.

The heel is now again examined manually. (At this point we are to make our check-up roentgenograms, if possible, for we have found that check-ups through plaster are quite unsatisfactory.)

Tightly folded sterile dressings are placed over the stab wounds in the heel and held in place by a sterile gauze strip wound about it A snug roll of felt four inches by one and one fourth inches is now carefully placed at a very slightly oblique angle beneath each malleolus [see Fig 951]

A circular low plaster of paris is then applied with the foot in slight inversion and in extreme plantar flexion While this is hardening manual pressure is applied over the pad areas [see Fig 952]

In those cases where more certain relaxation of the tendo achillis is desired a high midthigh plaster is applied with the knee flexed and the foot plantar flexed Such cases are those in which the angle of incidence has been markedly decreased or obliterated [See Figs 953 956]

Fig 955 Prereduction axial view of Figs 953 (left hand illustration) and 954 (*left*)

After care

1 The first plaster is removed in two weeks The submalleolar pads are carefully replaced and with the foot at right angles a new circular encasement is applied

2 A new circular plaster and pads are applied every two weeks up to 10 or occasionally 12 weeks We do this so as to maintain constant snug pressure beneath the malleoli and it gives us a chance to check up on local conditions (This has taught us during the last decade and more that such pressure surely retards callus formation and consequently we have been very careful in the placing of corrective pressure pads or appliances in other types of fractures)

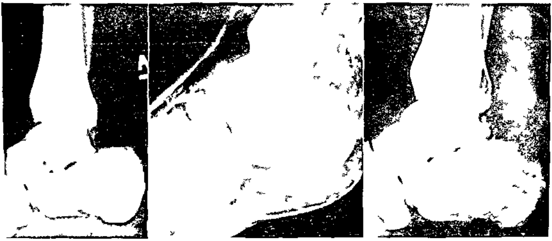


Fig 954 (*Left*) Lateral x ray view of left os calcis of case shown in Fig 945 Again note marked comminution into subastragalar joint and pushing up of heel
(*Center*) Postreduction x ray view of subject shown in left hand illustration above
(*Right*) Lateral view of subject shown in left hand illustration above

3 After removal of the last plaster the special ambulatory os calcis splint (for which the patient has been measured just before application of this last plaster) is applied at once This immediate application of the brace is important since the pressure pads will be more effective than if applied later when edema is present [Figs 957 959]

4 Daily massage active foot and ankle motions gradually increasing toe and heel and foot rocking exercises supination plank walking and radiant heat or hot soaks are also begun after removal of the last cast (The author has now established a regular class at the Boston City Hospital where these exercises are given under the direction of a trained physiotherapist)

5. Full weight-bearing without crutches, but with an ambulatory splint, is begun from ten days to two weeks after removal of the last plaster. By that time the foot, ankle, and leg muscles should have regained their tonicity by the daily physiotherapy routine. Greater comfort during the beginning of this weight-bearing period may often be obtained by a one-sixth-inch Thomas heel and a well-fitting inner sole with a pocket for anterior and plantar arch pads.

6. At the end of another six weeks (four and one-half months following initial reduction), the ambulatory splints are gradually discarded, and the patient is instructed as to more strenuous foot exercise and increased walking on rough surfaces. It is during the early part of the direct weight-bearing period that careful record is made of the patient's pain symptoms If the patient complains of persistent pain in the affected subastragalar-joint region, and the original fracture was of the intra-articular type and comminuted, then and then only do we consider fusion of the subastragalar joint. [For subastragalar fusion, see Chapters 7 and 15 —Ed] In the rare case, where there was originally marked subluxation in the calcaneocuboid or astragaloscaphoid joints, which has not been wholly corrected, and the patient has definite pain there, a triple arthrodesis is considered [See Chapter 7.] Again, where there is definite pain in the tendo achillis, a lengthening of that tendon is considered. [See tendon lengthening, Chapter 7 —Ed] Where there is submalleolar impingement pain, due to a repiling-up beneath the

Fig. 956. (*Top, left*) Prereduction lateral view of fracture of os calcis with comminution into joint.
(*Top, right*) Prereduction axial view of same case.
(*Bottom, left*) Postreduction lateral view of same case.
(*Bottom, right*) Postreduction axial view of same case

external malleolus the piled up bone is removed by operation Finally in the very exceptional case where the heel has been drawn up markedly and has not been successfully pulled down and held, with resultant flat heel a Gleich operation is considered

End results in the 152 Cases of Fracture of the Os Calcis

Result	*Cases*	*Per Cent*
Good	111	73
Fair	21	14
Poor	20	13
Totals	152	100

The foot and ankle are now firmly held by the left hand and with the right hand the heel is manipulated laterally with repeated thrusts until the fracture has been thoroughly disimpacted Any upward displacement of the os calcis is corrected by grasping the heel with the one hand the forward portion of the foot with the other hand and then pulling the sole of the foot with a sudden thrust against a vertical bar The broadened but now loosened bones are squeezed into place with an os calcis clamp All of the procedures are done with the knee flexed and the foot in plantar flexion

A well molded boot cast is applied with the foot in full plantar flexion Constant traction on the heel is used while the cast is molded under the malleoli over the back of the heel and under the arch of the foot

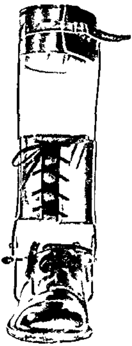
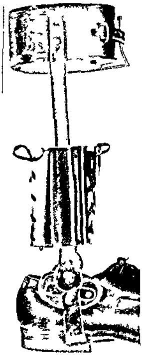
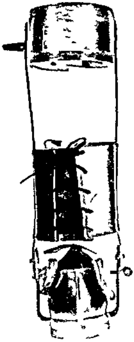




FIG 957 (*Left*) Front view of os calcis ambulatory brace Note hinge at ankle and submalleolar pads
FIG 958 (*Center*) Side view of os calcis brace shown in Fig 957
FIG 959 (*Right*) Rear view of os calcis brace shown in Fig 957

Another conservative type of os calcis fracture therapy is that devised by O W Yoerg[17] of Minneapolis It is best described in his words

We anesthetize the patient with a general anesthetic to obtain complete relaxation of the muscles of the leg The patient is placed on the affected side so that the foot can be brought to the edge of the table, with the heel extended over the edge

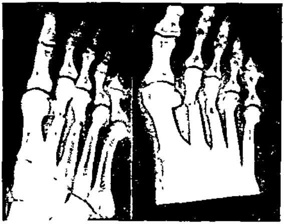
After reduction and the application of the cast the patient is placed in bed with the foot elevated He is kept in bed for three or four days, or until his pain had disappeared Many of these patients in spite of the fact that the fracture is forcibly manipulated have little or no pain following reduction When pain has

subsided and we feel that there is no more likelihood of pull from the calf muscles, the *patient is allowed to be up and about, using* his crutches He is d.scharged from the hospital, but is not allowed weight-bearing on the injured foot Four weeks after reduction *the patient returns and the cast is removed.* Radiographs will show union taking place and that it is sufficiently strong so that a cast is no longer necessary The patient is then *instructed to massage and to actively and passively* move the foot and ankle Particularly is he instructed to evert and invert the foot to bring about a return of motion in the sub-*astragalar joint. He continues this massage* and manipulation for a period of four weeks but is not allowed weight-bearing. He returns again at the end of four weeks, or two months *after reduction. The radiographs then taken* will show that union is firm He is allowed to walk on the injured foot using crutches In the ordinary type of fracture he does so with *little or no pain,* and, *in a few days or a week,* in most instances, will discard his crutches and walk without support.

Still another and quite widely used so-called conservative method of treating these fractures is the one devised by Dr. Lorenz Bohler.[13] This method is somewhat more complicated than the preceding two:

> By means of traction in the axis of the calcaneus and in the axis of the leg, and by the plantar flexion and pronation of the front part of the foot, the angulation, the shortening, and to some extent the widening of the heel bone will be reduced The talus is pulled away from the calcaneus and the joint between the two bones once more restored. The widened bone is compressed by the application of the compression clamp while the longitudinal traction is kept up . . .

For further detailed description of this method the reader is referred to Bohler's[8] textbook, Treatment of Fractures. [In the Böhler method of treatment, skeletal traction is made by a steel pin through the upper posterior part of the os calcis, downward and backward, with countertraction maintained in an upward and forward direction by a pin through the lower tibial shaft, the leg resting on a Braun frame, and a compressor is used for lateral com-



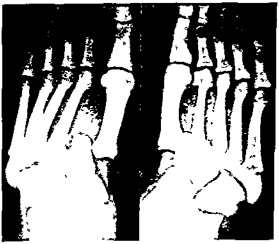


FIG. 960 (*Top*) Fracture of second and *third metatarsals Treated by wire traction,* plaster boot, with stout wire loop incorporated in it.

FIG. 961. (*Center*) Comminuted fracture of *first metatarsal.* Treated by wire traction as in Fig. 960.

FIG. 962. (*Bottom*) Dislocation of first metatarsal at the metatarso-cuneiform joint complicated by fractures of bases of other metatarsals.

pression as with the Forrester clamp A technic of reduction along similar lines is provided by the Haynes Stader and Roger Anderson apparatuses (See Chapter 22) —Ed]

The avulsion type fracture of the os calcis in which the tendo achillis pulls out a more or less triangular piece of bone from the back of the os calcis requires an open operation in most cases This consists simply in exposing the site of fracture through a posterior incision replacing the torn off fragment anchoring it by suture or by nail

FIG 963 Case shown in Fig 962 treated by wire traction cast and banjo splint

and then with foot in plantar flexion applying a circular plaster of paris This should be removed in two weeks time the sutures removed and a new plaster applied with the foot held in a position midway between the initial postoperative one and a right angle In another week or so this can again be replaced by a light plaster of paris boot with the foot in a neutral position This is retained until union is established (usually in another week or so) and then physiotherapy is begun Guarded weight bearing can soon follow The disability period is about eight to ten weeks depending upon the patient his occupational demands and the speed of union

FRACTURES OF METATARSALS

These fractures occur more often than is suspected and are too frequently overlooked until persistent pain on weight bearing has called attention to the possibility of the lesion There are two types of metatarsal fractures caused by prolonged strain (as in soldiers on long marches or in nurses with continuous hours on hard floors) or by dancing or running They are known respectively as the march foot or pied force and the dancing fracture

The march foot is generally a fracture through the shaft (middle) of the second and sometimes the third metatarsal bones It appears as a rule without any real acute traumatic history Such an injury shows soft tissue reaction in the dorsum of the foot (swelling and so forth) and localized pain and tenderness over the affected metatarsal bone These cases require initial rest elevation and continued local heat Then when tissue reaction has subsided a low snug plaster of paris encasement is applied This is retained for about a month and is followed by a well fitted shoe equipped with a metatarsal bar and a leather inner sole with a plantar pocket for felt pads Well directed physiotherapy must also be given such a case at that time It should consist of local heat (hot whirlpool bath) massage and foot and ankle exercises and should be continued until all local signs have subsided

The dancing fracture as Sinclair[14] states affects the styloid of the fifth metatarsal It is quite painful and crippling and is generally of some economic importance to the victims of such an injury The treatment of such a fracture is practically as outlined below in regard to simple metatarsal fractures

A simple fracture of a metatarsal without displacement needs only a well molded plaster of paris boot The fixation however should be retained for seven or eight weeks and then weight bearing should usually be

resumed. It must be remembered that too early and sudden weight-bearing causes formation of excess callus which, as a rule, is quite painful. These fractures act, in this respect, much like the fractures of the os calcis. During this gradual return to weight-bearing, massage, local foot and toe exercises, and heat should be given. Also, the patient's foot should be fitted to a molded semi-rigid steel foot plate or a well-fitting leather inner sole as already described. The average time required for a return to normalcy is about 12 weeks (Fig. 960).

In fractures with displacement the reduction requires a local or general anesthetic. It is well to note here that although lateral displacement may not cause later disability, plantar deformity is apt to give pain during the convalescent period. In those cases where ordinary traction and manipulation give good reposition, and where there is no immediate tendency to slip out of position, a simple molded plaster-of-paris boot is all that is needed for fixation. The rest of the treatment is the same as already outlined.

If, however, manual traction and manipulation do not succeed in replacing the fracture fragments, or in cases where there is marked comminution, the procedure is to insert Kirschner wires through the toe or toes of the affected metatarsal bones and, with traction on them, to draw and manipulate the fragments into position. If the procedure is successful, a snug plaster-of-paris boot is applied, the traction being continued, maintained by attaching it with rubber bands to a loop of wire incorporated in the plaster boot (a form of banjo splinting). This traction is maintained for three or four weeks. A fresh snug plaster-of-paris boot is applied following the removal of the wire traction with the old one. The second boot is retained for another four or five weeks and then the gradual weight-bearing period is begun with the customary physiotherapy and arch support (Figs. 961-964).

When reposition is not obtained by this method, recourse must be had to open reduction. For the internal fixation in these cases following reduction, the author advocates the use of special miniature steel plates and screws which he first devised and used on metacarpal and phalangeal fractures several years ago and which have been improved upon by suggestions from Dr. William Sherman of Pittsburgh. By the application of these plates and screws the reduction is maintained with a certainty that the author never experienced with ordinary drilling and catgut or fine wire ties. In fact, he considers their use in multiple metatarsal fractures with displacement

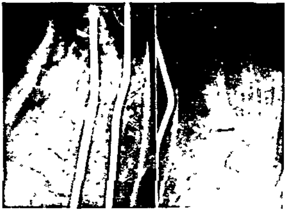


FIG. 964. X-ray views of Fig. 963.

really to be the method of election. Following such fixation only a light boot is necessary which can be bivalved in three or four weeks, when physiotherapy is begun. However, even in these cases weight-bearing should not begin too early lest there be *painful excess callus formation (Fig. 965).*

In concluding the subject of metatarsal fracture therapy it must be mentioned that subfascial hemorrhage of the dorsum of the foot sometimes complicates a metatarsal fracture and crushing trauma to the foot. One of the author's former teaching residents, Dr. H. M. Childress,[15] has written a paper on "Subfascial Haematoma as a Complication of Crushing Injuries to the Foot" in which he recommends immediate incisions to release and remove the sub-

fascial hematoma He believes that release by transverse section of the cruciate and transverse ligaments of the foot and ankle should be considered in persistent circulatory block and that delayed or inadequate treatment results in the so called congealed foot or in necrosis of the soft tissues of the dorsal forefoot and toes

FRACTURES OF SESAMOID BONES

Sesamoid bones and other variations in the tarsal and metatarsal area must be considered in foot fractures The diagrams reproduced from Holmes and Ruggles[9]

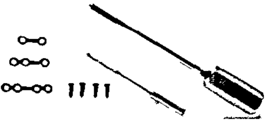


FIG 965 Miniature bone plating outfit Plate 2 hole ¾ inches long ¼ inch wide at widest part Plate 3 hole 1¼ inches long ¼ inch wide at widest part Plate 4 hole 1¾ inches long ¼ inch wide at widest part Screws 5/32 inch long Screwdriver 4¾ inches long Drill point 2¾ inches long Size 44 Plates and screws of vanadium steel

Roentgen Interpretation give a clear idea of them (see Figs 936 and 937)

Fractures of the sesamoid bones are quite uncommon but when they do occur they cause marked pain at every step in walking A most careful x ray examination and interpretation must be made in suspected cases The treatment of fractures of the sesamoid bones under the head of the first metatarsal consists in the application of a snug fitting low leg plaster of paris boot This is retained for from four to six weeks when definite callus formation is seen by x ray

Following the removal of the plaster the treatment as laid down by Hauser[16] should be followed The patient should wear a comfortable shoe fitted preferably with a transverse bar on the outside to take the weight off the region of the heads of the metatarsal bones A slight raise is applied to the heel of the shoe on the inner side In another three weeks or so the bar is higher on the outer than on the inner side and the patient is trained to walk so that the ball of the toe receives most of the weight When normalcy is restored the patient returns to his regular footgear

In those cases where pain persists in spite of that treatment the offending sesamoid should be removed And as G Morrison[1] has stated the incision must be placed as advantageously as possible to avoid a painful scar The usual approach is through a medial plantar incision or through a small curved plantar incision just distal to the end of the first metatarsal

FRACTURES OF PHALANGES OF TOES

It is more or less generally agreed that fractures of the terminal and middle phalanges of the toes give comparatively little trouble and are not very disabling The treatment may consist in (1) simple adhesive strapping of the affected toe tying it up to its neighbor or (2) a simple splinting by one of the several pliable aluminum splints which fit over the toe Fixation in such cases can be maintained for two or three weeks However it should be stressed here that as Forrester says the age of the patient and the possibility of diabetes are always advisable to take into consideration in these cases

Fractures of the proximal toe phalanges without displacement may be treated quite simply by means of a well molded plaster boot which is retained for from two to three weeks A wooden plantar splint cut to the shape of the foot but extending somewhat beyond the toes with appropriate felt padding and strapped firmly to the sole of the foot by means of adhesive strapping is also a simple type of fixation

Where there is displacement in such a fracture, there is first the problem of reduction, and, secondly, maintenance of this by fixation. Where reduction is easily done a simple well-molded plaster-of-paris boot may be all that is necessary. This should be retained for three weeks or more until union has been established. Where replacement is difficult to maintain, or where it has a tendency to angulate dorsally, a thin Kirschner wire should be inserted through the toe and traction maintained by means of a banjo wire splint incorporated in a snug plaster-of-paris boot. This traction should be maintained for from two to three weeks and then a well-fitted walking plaster boot applied and retained for another two weeks or so until the bony union is firm.

In very obstinate cases, or in cases of multiple phalangeal fractures where even wire traction does not give good reposition, open reduction and fixation by means of miniature plates and screws is advised.

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SECTION TWELVE

PRAINS, SPRAIN-FRACTURES, MUSCLE AND TENDON INJURIES

41

Treatment of Sprains Including Marginal Joint Fractures

PAUL H. HARMON, M.D.

General. The seriousness of sprains is often not fully considered by the general surgeon and others who undertake to treat them. These injuries require the same amount of care in diagnosis and treatment as fractures or more extensive injuries involving the joints. The injury producing the sprain is frequently the same as or similar to that producing a fracture into the joint except that in the former there is no break in the bone. There may or may not be displacements of the joint surfaces, depending upon whether laceration of the ligaments allows such bony displacements. The extent and type of ligamentous injury must be definitely decided before the treatment of sprains can be carried out.

A sprain is defined as a trauma to a joint characterized usually by ligament injury and occasionally by damage to adjacent tendons. If untreated, pain, swelling, and functional disability in proportion to the type and extent of the injury are seen. In the usual types of sprains, unaccompanied by joint, tendon, or muscle displacement, much pain and subsequent disability can be forestalled by prompt injection of a local anesthetic agent; this treatment is recommended by the author. It should be pointed out that there is no hard-and-fast line as to where a sprain ends and marginal fracture begins. Chips of bone are sheared from the underlying bone, and ligaments are stretched or torn in identical injuries of joints. The varied type of injuries that have, in the past, masqueraded as "sprains" has not been fully appreciated until recent years when injuries have been regularly subjected to roentgen diagnosis and close scrutiny.

It is important that patients who suffer sprains be returned to their functional usefulness and occupation as soon as possible The newer methods of treatment, which include local anesthetization of the injured area, allow the patient to use the extremity from the earliest moment Edema of the ligaments and other periarticular structures is thus reduced, since active use improves the circulation of the part Swelling, on the other hand, is favored by the older treatments which utilize immobilization. This discussion of sprains will stress early functional return which depends upon exact diagnosis of each injury, since effective treatment can be based only upon such considerations.

The treatment of injuries by rest and immobilization had been practiced routinely until its efficiency began to be questioned by certain radicals such as David (1779) and Lucas-Championnière (1889), who witnessed the stiffened joints that resulted in certain types of fractures from prolonged immobilization. Their influence,

however was lessened by general inertia and by the positive advocacy of rest by the English school (Hugh Owen Thomas and Sir Robert Jones) only to be fully vindicated and properly placed by modern technic As in other controversies there was some element of truth in both principles it remaining to modern detailed diagnostic analysis to employ the correct quantities of both rest and motion in each injury An exact and complicated balance of rest and directed active and/or passive motion (physiotherapy) is now utilized in the postoperative or after treatment of injuries These detailed schedules of rest and motion will be presented with each injury

Three modern surgeons who have contributed fundamentals to the treatment of bone and joint injuries are Sir Robert Jones (1855 1933) L Bohler and R Leriche Sir Robert Jones emphasized the necessity of gentleness and exactness followed by prolonged and absolute rest in the treatment and reduction of fractures and joint injuries

The work of Bohler marks the modern revolution in the treatment of bone and joint injuries from the rest technic to one where function is maintained in proper support at the onset of the injury This author popularized the immobilization of fractured fragments by sterile nails and pins and the skin tight plaster He demonstrated the technic of local anesthesia by the injection of novocaine into the fractured area thus disproving a concept held for many years that the fresh hematoma of a fracture could be easily infected

Bohler described his principles as follows

> The broken limb can be made to function in the best and quickest manner if the broken fragments are restored to position as exactly as possible and if during the period of necessary fixation which follows appropriate measures are taken for the prevention of muscle wasting stiffness of the joints and damage to the circulation Active movements are superior to passive in the following respect active motion can always be carried out by the injured person passive movements at the most can be applied for one or two periods daily while during the remaining hours he is a sick man and suffers pain

[It is perhaps an exaggeration to designate the work of Bohler as revolutionizing the treatment of injury and to imply that it involved new principles or practices It is correct to say that he did much to popularize the principles and practices evolved by others and developed an excellent organization for seeing that they were adequately carried out Ed]

Leriche has been the recent advocate of deadening by local anesthesia the joint pain of sprains and the acute injuries to the soft tissues stressing the abolition of circulatory changes and the possibility of early function which result He believed that the circulatory changes following trauma are due to sensory nerve ending stimulation by edema and by lacerated tissue which afferent impulses produce reflex vasodilatation Opening up the arteries produces further effusion and the latter more intense sensory impulses This constitutes a vicious circle which can be broken only by abolishing the sensory stimulation by a local anesthetic or minimizing the swelling by local support

The modern system of treatment of sprains and other painful myofascial syndromes is based upon the principles of Leriche added to the early and active motion advocated by Bohler The results are immediately pleasing to the patient and a rapid recovery ensues At times immobilization must be utilized as the major method in the treatment of a special condition and direct operative attack is likewise often indicated The promotion of weight bearing and a certain amount of motion accelerates recovery from operation

[It is essential that it be understood that the injection of local anesthetic is not for the purpose of pain relief per se but for the purpose of *allowing resumption of normal or nearly normal function thereby* Unless

functional activity is enforced, the injection becomes relatively valueless.—Ed.]

GENERAL METHODS: DIAGNOSIS, DIFFERENTIAL DIAGNOSIS, AND TREATMENT OF SPRAINS

Every joint which does not need to be immobilized must be actively exercised from the first day of injury. Failure to obey may be responsible for complications which remain permanently despite treatment.—R. WATSON-JONES.

Those who treat sprains and other injuries should follow a routine method of examination, including a written history of the injury with data upon the time, place, circumstances, and witnesses to the accident or trauma. These data are essential for both patient and surgeon for reports, and for later contact with the case in the event of settlements and medicolegal complications.

The injection of novocaine into a painful area is as much a diagnostic as a therapeutic procedure. Special sprains where specific treatment is indicated (complete tear of the lateral ligament of the ankle, tibiofibular joint separations of minor degree, "reflex" sciatica, periarthritis of the shoulder in the presence of greater tuberosity tenderness, etc) can be detected only by abolishing pain, which is best done by local injection anesthesia. Records should include joint range and appearance after local anesthesia. The only contraindication to the use of novocaine for diagnostic purposes is the presence of a heavily contaminated open wound directly over the proposed site of injection or the history of special idiosyncrasy to the drug.

Present-day practice demands that every injury be subjected to roentgen diagnosis if at all possible. To neglect to do so may be interpreted as malpractice Chip fractures and marginal joint fractures differ from simple sprains not only upon the roentgen film but also in subsequent history. Injuries and diseases of the epiphyses, the quiet or aseptic necrosis of bone, accessory bones and other anatomic variants, and bone atrophy and disease should be excluded by the roentgen ray before active treatment of an alleged injury is undertaken. Fluoroscopic screening for the examination for fracture should not be used extensively because of the attendant danger and because the poor bone detail will cause certain injuries to be missed. Medicolegal requirements make it a wise precaution to see that

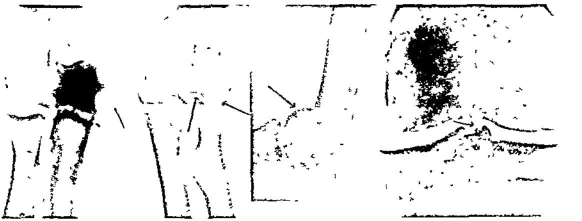


FIG 966 Roentgenograms demonstrating intra-articular bodies frequently unassociated with injury or fracture and wrongly diagnosed sprain (*Left*) Osteochondritis dissecans of elbow Loose body near defect from which it arose. (*Center illustrations*) Intra-articular loose body in adult from recent fracture of lateral portion of trochlea (*Right*) Osteochondritis dissecans of knee. Arrows indicate loose bodies.

films of every injury are retained in the files

In the past certain small bone injuries and injuries auxiliary to certain fractures have been relegated to the category of sprains by neglect of such special modern methods as three plane roentgen examinations stereoscopic films interval roentgen examinations and roentgen examinations in

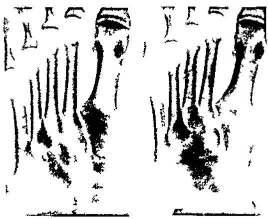


FIG 967 Roentgenograms showing march fracture (*Left*) Anteroposterior view of foot on occasion of patient s first visit Although pain in foot was present this film fails to visualize bone injury (*Right*) Similar view of same foot four weeks later One can see a fracture line in the third metatarsal which is surrounded by calcification in the subperiosteal zone This injury is often mistaken for bone tumor by roentgen ray and for sprain clinically

different joint positions Oblique views are of special value in demonstrating chip fractures of the small bones of the wrist ankle hand and foot the distal end of the radius and ulna tibia and fibula and for visualization of the intervertebral pedicles

Stereoscopic paired films of the major joints are useful in accurately locating intra articular bodies (Fig 966) bone islands foreign bodies etc which under certain conditions may be misinterpreted as marginal fractures Even if the first roentgen films show no fracture later films taken after five to ten days may easily demonstrate the line of fracture or indirect evidence such as calcification under the elevated periosteum The former situation is commonly encountered in the small bones of the wrist and foot while the so-called march fracture of the metatarsals (Fig 967) metacarpals and many other bones are instances of the latter Auxiliary roentgenograms in flexion and/or extension of a joint may successfully demonstrate a marginal or joint fracture when the usual films in the neutral position of the joint will fail to show the injury These special methods are cited because their careful application will result in accurate diagnosis Many chronic sprains in the past were injuries which could have had appropriate treatment if more care had been followed in the original diagnosis of the injury Fig 968 shows the roentgenograms of several cases which had been erroneously diagnosed in the absence of such films as sprains

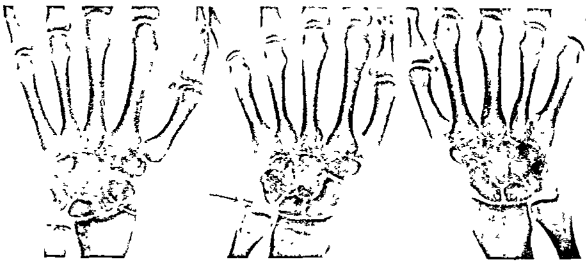
The lesions of bones that are collectively classified as *quiet or aseptic necrosis of bone* have received recognition and increased attention during the past two decades Many of these conditions (Fig 969) present themselves to the physician as a painful joint of varying degrees of severity and may simulate sprains since a history of trauma is often obtained These bony changes are found about the hip knee and foot usually in the growing child or adolescent Fig 969 reveals certain special examples The aseptic necrosis of the tibial tubercle (Osgood Schlatter s disease) and similar changes in the tarsal navicular (Kohler s disease) in the distal heads of the metatarsals and the epiphyses of the phalanges often give a history of trauma The treatment of these lesions is discussed in another section of this volume [see Chapter 18]

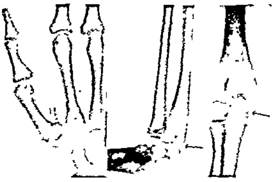
Aseptic necrosis of certain bony fragments frequently occurs in marginal or chip fractures and in fractures or dislocations of certain small bones particularly of the proximal carpus and in the astragalus The

site of injury of these latter bones plays an important part in determining whether they will undergo aseptic necrosis, as the deprivation of blood supply is often a function of the direct injury of blood vessels. Many a chronic sprain will be found to be actually a fracture which has continued to be painful because of arthritic changes produced by use *in the absence of adequate* blood supply. A typical example of such a chronic sprain is the history given with Fig. 968 A and B, where in the first instance the patient suffered mild recurrent wrist pain for nine years and in the latter instance for six months before the roentgen ray demonstrated the cause of pain.

An intact nervous pathway for all types of sensation, particularly joint and deep sensation, apparently protects the normal person from injuries which would otherwise produce marginal fractures and minor bone injuries. Examples of the lack of deep sensation are commonly found in the neuropathic joint of tabes dorsalis, designated as a Charcot joint. While the advanced physical and roentgen appearances of these joints are familiar, the first and early injuries are less well known and are fre-

A B





C D E

Fig. 968. Roentgenograms of several cases which had been diagnosed erroneously as sprains Many had never been subjected to roentgen examination when the original diagnosis of 'sprain" was made. (A) Old ununited fracture of carpal navicular. This patient suffered a "wrist sprain" in a football game, which continued to be painful for many months and then ceased to annoy him Nine years later in a particularly severe recrudescence of pain the patient, then a surgeon himself, had this roentgenogram taken (B) Congenitally separate center of ossification for ulnar styloid. This had never given patient pain until he suffered a "wrist sprain" six months previously It had continued to give rise to symptoms. (C) Anteroposterior roentgenogram showing fracture at base of first metatarsal, clinically similar to a "sprain." (D) and (E) Anteroposterior and lateral roentgenograms of an impacted fracture of proximal ulna, said to have been a "sprain." See also Figs. 976-978, 980, 981, and 985.

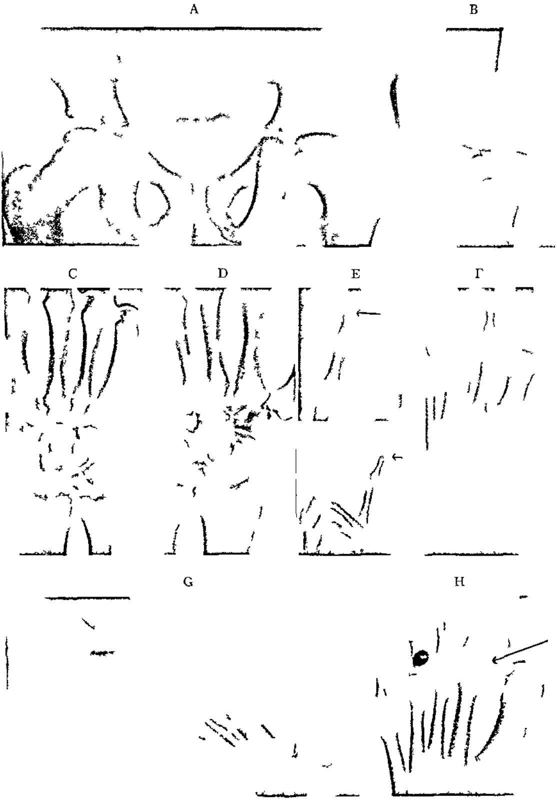


Fig 969 See legend p 1139

quently mistaken for marginal fractures or sprains (Fig. 970). Every marginal or joint fracture which has occurred after relatively insignificant trauma may be suspected of being a Charcot joint. Such a suspicion can be confirmed or eliminated by examination and serologic tests.

From the point of view of individual accidents, disability due thereto, and other factors where insurance coverage is involved, sprains are important because an accurate diagnosis allows accurate prognosis to be given. It is of double importance to return such patients to their gainful occupation as early as possible, consistent with sound treatment. It should be further pointed out that the treatment of sprains unaccompanied by joint dislocations and other injuries can be carried out entirely as an ambulatory type of treatment with minimal disability when local anesthetics are used to control acute pain of the injury. The patient can thus use his extremity from the beginning.

There are certain types of occupations which predispose to certain types of sprains and injuries. In an adequate history the relation of sprains and other injuries to occupation should always be noted.

Treatment

After the diagnosis has been definitely established and after marginal fracture and bone disease are ruled out by roentgen examination, only then is the patient to be considered as a candidate for treatment by the injection of local anesthesia, and by early use with or without weight-bearing. The older idea that local anesthetics destroyed pain, which sign was considered as Nature's warning to no longer use the part, is a half-truth except in instances where gross fracture can be demonstrated by the roentgen ray. There is still, however, undeserved widespread prejudice against this method. Those who have used it extensively consider it the treatment of election (Leriche, Moynahan, and in this country Ware, Outland, and others). The technic is carried out as follows:

The point or points of maximum tenderness are found, and will usually be no larger than a centimeter in diameter. There may be several such points. The skin is prepared with half strength tincture of iodine or other suitable skin disinfectant after cleansing The part is draped and the anesthetic solution infiltrated about the local prominent bony landmarks and into the torn ligaments through a small preliminary skin wheal. The injection should be painless after the preliminary skin wheal is raised. Usually 10 to 30 cc. of the solution suffice. The solution to be used for this purpose will depend somewhat upon the experience and individual preference of the operator. 0 5 or 1 per cent novocaine is entirely satisfactory, but the author has recently used and prefers 0.5 per cent novocaine to which one-tenth of 1 per cent *eucupin dihydrochloride* (iso-amyl-hydrocupreine dihydrochloride) has been added. This latter anesthetic substance has a prolonged time of action.

The patient should be carefully instructed upon the phenomena to be observed. The sprained area becomes painless immediately, the patient being astonished that he can walk or use the extremity without discomfort. He should be instructed that dull pain and a throbby sensation will return in from one to four hours (novocaine) or in from three to eight hours (novocaine-eucupin); this discomfort is never so severe as the original pain. The patient should be

Fig. 969. Instances of aseptic necrosis of bone. These conditions frequently enter into differential diagnosis of sprains. (A) Coxa plana or Legg-Calvé-Perthes disease of hip; (B) Osgood-Schlatter's disease of tibial tubercle; (C) and (D) ancient bilateral aseptic necrosis of lunate in a man without a traumatic history; (E) aseptic necrosis of epiphysis of distal phalanx in traumatic injury to finger; (F) and (G) aseptic necrosis of tarsal navicular (Köhler's disease); (H) aseptic necrosis of second metatarsal head.

instructed to continue to use the joint By the next day or by the latest 48 hours later most of the discomfort is gone This average schedule of relief is modified by several factors (1) The extent of the ligamentous injury (2) the presence of hemorrhage and (3) the willingness and ability of the patient to cooperate There are many to whom the treatment cannot be successfully applied they are in general the group of persons who for psychic reasons are poor subjects for surgery under local anesthesia Persons with ligamentous injury received in athletics are especially good subjects for it Special points in technic will be described in connection with any joint where deviations from the above general description warrant it Illustrative cases follow

[The injection of local anesthetic in pure sprain cases often can be paralleled by the use of skin analgesia secured by the use of an ethyl chloride spray The rationale of the procedure is the same as that underlying the injection therapy the abolition of local pain and tenderness in order that active exercise and use can be enforced Although there is no unanimity of opinion as to the mechanism whereby pain and tenderness are abolished by the securing of skin anesthesia it is empirically a fact The most commonly accepted explanation is that the skin anesthesia results in the breaking of the reflex arc which is otherwise responsible for vascular and muscle spasm As with the injection method the elimination of pain and tenderness is useless if active motion and use are not secured and if the results are not satisfactory one should seriously consider the probability of there being more than a mere sprain in the part affected

Fig 970 Case of early neuropathic Charcot joint (knee) frequently mistaken for marginal fractures and for sprains when roentgen and physical and serologic examinations are not done

The technic of this procedure is difficult time consuming and detailed Mere spraying of the skin to secure anesthesia is not productive of results

The patient is told that an attempt is to be made to get rid of his pain and soreness by spraying a cold solution on his foot (or leg or back) and that if the desired result can be secured he will be able to use the affected part if he does not allow it to stiffen up

The points of tenderness are then carefully mapped out and marked The skin is covered by some oily solution (camphorated

oil is very satisfactory) to protect it from freezing. This is gently rubbed in. Starting with the tenderest spot, each area of tenderness is successively sprayed with ethyl chloride, to the accompaniment of gentle massage, until it is no longer tender. As the spraying proceeds from spot to spot, the patient is urged to actively exercise the ankle within pain limits. Care is taken to temporarily discontinue the spray just as soon as the skin starts to whiten. It is promptly resumed when the whiteness disappears. If and when all tenderness can be eliminated, and the patient can move his foot in all planes without pain, he is started walking —slowly at first, and then at a fairly rapid pace, emphasis being laid on walking without a limp. He is told that if he finds the part stiffening up it indicates the need for further exercise The general course is quite comparable to that following actual anesthetic injection. In the event of failure to respond to this treatment, careful examination for the existence of a lesion more severe than a sprain should be carried out It may be used, therefore, as a diagnostic as well as a therapeutic procedure.

It has been stated that there is a large element of applied psychology involved in the success of this therapy That may well be, but if the results are satisfactory this is no criticism of the method.—Ed.]

Case 1. Wrist Sprain. J. G, female, aged 11, fell upon her flexed hand against a cement-walled building There was immediate and forced ventral flexion of the wrist followed by swelling on the dorsum of the wrist and inability to move this joint and the fingers without pain When examined one and one-half hours later at the Guthrie Clinic and the Robert Packer Hospital, a dome-shaped tumor was found on the dorsum of the wrist, the height of which was about a centimeter above the surrounding tissues. The patient was unable to move the wrist more than 5 or 10° without pain. We did not examine the patient for the classic signs of fracture because she would have suffered additional pain. Roentgen examination of the joint, performed immediately, failed to show fracture or dislocation.

Re-examination showed maximum tenderness to be located in a centimeter-circular zone, located about a centimeter ulnarward from the radial styloid This point was injected with 5 cc. of 0 5 per cent

Fig. 971 Composite photograph showing range of motion in sprain of lateral ligaments of knee, three days after injection of painful areas with novocaine-eucupin followed by ambulation.

novocaine solution containing 0.1 per cent of eucupin after 2 cc. of blood were aspirated from the "tumor" which was a hematoma. The patient was able to use the wrist immediately without pain and was sent home without support with instructions to continue use. She returned the following day stating that she had been able to use the wrist fully and without pain until the following morning, when upon awakening it was "stiff" and throbbed upon attempts at

dorsal and palmar flexion The painful area was again injected with the same solution in the same amount with immediate return of a full range of painless motion From this date the discomfort suffered by the patient was negligible

Case 2 Sprain of Lateral Ligaments of Knee by a Football Player M C male aged 18 was brought to the Guthrie Clinic and the Robert Packer Hospital in a wheel chair He had injured the right knee in foot ball practice two hours previously and was unable to bear weight upon the knee with out pain There had been no locking Roent gen examination of the knee showed no fracture dislocation or abnormality of the bone Physical examination showed two points of maximum tenderness each about 2 cm below the uppermost palpable point of the right tibia one on the mesial side of the knee and the other on the lateral side There was no abnormal mobility of the knee

A diagnosis of sprain of the lateral and mesial ligaments was made and each pain ful area was injected with 8 cc of 0 5 per cent novocaine containing one tenth of 1 per cent eucupin The patient was able to walk upon the extremity immediately with a limp but still complained of slight to mod erate deep tenderness He was encour aged and cooperated in continuing to walk despite the residual soreness Limp and deep tenderness continued for four days but by the fifth he was totally relieved except for morning stiffness during three additional days (Fig 971)

The complications of the novocaine re action' can be avoided by the usual steps of avoiding injection into a blood vessel by aspiration through the needle before injec tion and by giving amytal or other bar biturate sedative to the more apprehensive patients If abnormal joint mobility is dis covered after injection such a finding means extensive and significant ligamentous tear which must be treated by either sur gical repair, prolonged immobilization, or both, as indicated Abnormal joint mobility is especially important in the knee and the ankle the weight bearing joints and will be considered in the discussion of these joints Roughly one quarter of the sprains deemed suitable for treatment by injection are not fully relieved by it this calls for careful re examination and injection of any other painful points that may not have been dis covered at the first examination having been overshadowed by more intensive pain in a neighboring area

When chip fractures are present although the lesion is essentially a sprain many can be treated by excision of the bony frag ments and direct repair of ligaments Fol lowing such a procedure the patient may be returned to his full occupation in from one third to one half the time required if the injury is treated conservatively and is immobilized for the time the bony frag ments require to heal The following case is illustrative

Case 3 Excision of Free Mesial Mal leolar Fragment and Repair of Liga ments J P suffered an injury to the ankle which on radiographic examination was found to be a chip fracture from the antero mesial face of the tibia The size of the free fragment and its position were such that it was not necessary for osseous support of the ankle The fragment was excised under in filtration anesthesia (1 per cent novocaine) and repair of the ligaments done with chromic catgut A skin tight plaster was ap plied and the patient became ambulatory the next day with a walking iron The plas ter was allowed to remain in place for two weeks The patient used crutches in gradu ally resuming weight bearing during the en suing one week He returned to his occupa tion as a laborer 23 days after the injury

In the opinion of the author the method of converting these marginal joint fractures into a ligamentous injury by operative ex cision of the free fragment deserves wider application by those surgeons whose train ing and experience equip them for the

operative treatment of fractures. No free fragment should be excised, however, that is necessary for joint stability.

usually a fibrous fixation of joints or a "periarthritis." This tendency is just as great in sprains and ligamentous tears as

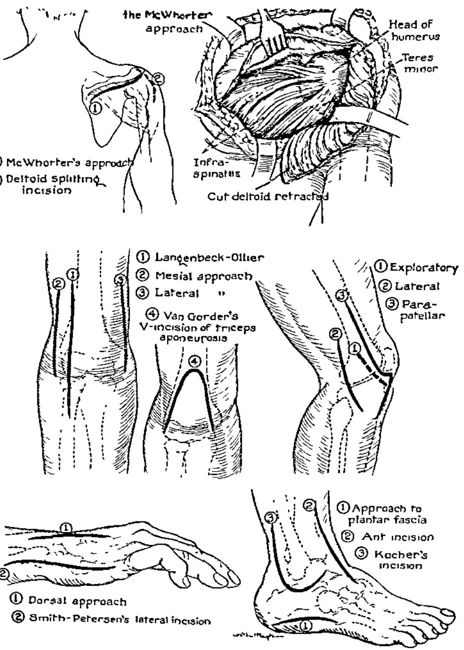


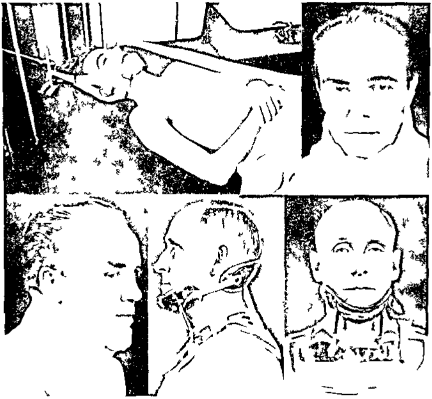
FIG 972. Selected approaches to joints that are likely to be of value in operative repair of ligamentous injuries.

Persons of sedentary occupations, those who are poorly muscled, and the aged are all prone to develop "arthritis" following injuries to the joints. This "arthritis" is it is in actual fracture. Prevention of this state, as is true in other situations, is far easier than treatment of the complication. Immobilization and disuse are the factors

resulting in this arthritic reaction The early mobilization of joint injuries as by the method just described seldom results in fibrous joint fixation with arthritic symptoms if the patient cooperates in the treatment

Conversely those who already have arthritic joints can be relieved for a greater or less period by injecting the carefully delineated pain points There are a number of recent publications upon this phase of the injection treatment The reader is referred to the appended bibliography [See also arthritis Chapter 15 —Ed]

A



C D E

Fig 973 Methods and apparatus used in treatment of painful spine (A) Head traction upon an inclined firm mattress (B) and (C) plaster support for cervical spine (D) and (E) Forrester cervical spine brace

thritic joints with or without demonstrable changes in the roentgenogram are exceptionally prone to sprains in which no hypermobility of the joints or ligamentous tear can be demonstrated after minor traumata Such painful joints are ideal for the application of the injection treatment Indeed many persons with painful arthritic

Bone atrophy especially the rapid and painful demineralization that occurs in certain persons following moderate or prolonged disuse of an extremity is not encountered in cases treated by this method nor can positional contractures develop such as might in those persons who would be indolent and uncooperative in the more

passive types of treatment which employ immobilization.

Whenever it becomes necessary to carry out surgical repair or investigation of a soft-tissue injury about a joint, the operation and subsequent recovery is usually promoted if one of the approaches illustrated in Fig. 972 is utilized. Many other new and valuable approaches have been devised in recent years.

INJURIES TO SPINE AND TRUNK

> The application of a plaster cast, without treatment by energetic work and exercise, damages the vertebrae still more than no treatment at all.—L. BOHLER.

Gross vertebral fracture and fracture-dislocations will not be described, their treatment is considered in Chapter 26. After roentgenographic study has ruled out fracture of the vertebrae, there remain a large number of injuries in which the chief complaint is pain located in the cervical spine or along the longitudinal spinal muscle bundles. This is particularly true in persons who have had previous history of chronic and recurrent back pain in the areas mentioned, frequently due to arthritic changes in the spine or its articular facets.

In treating pain located in the cervical spine, or pain over or in the shoulders referred from the cervical plexus after injury, head traction of three to seven pounds and physical therapy (radiant heat and massage) applied to the patient in strict recumbency for several days on an inclined firm mattress is usually successful in relieving the pain. In more severe and in persistently intractable cases, a plaster jacket or cervical spine brace may be necessary (Fig. 973). We have employed the paravertebral injection of novocaine (*without eucupin*) in the total amount of 100 cc. into multiple points along the cervical spine with relief for a variable period, especially in cervical-spine arthritis.

When located in the thoracic or lumbar zone, pain due to such injuries as just described is adequately controlled by the injection of 8 to 10 cc. of novocaine-eucupin solution into each paravertebral muscle bundle close to the spinous processes at the painful level. It is frequently necessary to repeat the injections one or two times at two-day intervals before lasting relief is secured. Care should be taken that the patient presents a fairly definite and recent history of trauma since the more chronic instances of back pain in the thoracic and upper lumbar areas do not yield to the injection of the local anesthetics in the paravertebral muscle bundles. Indeed, injection in such latter cases often aggravates rather than relieves the pain.

The same clinical picture is frequently seen in persons of middle or advanced age who have suffered severe trauma, but who have not sustained fractures. It is thought, in these cases, that arthritic processes have been subjected to trauma with resultant pain. The relief obtained from the injection of the local anesthetics is none the less certain. An illustrative case follows:

Case 4. Painful Post-traumatic Lumbar Spine Treated by Injection—Patient Known to Have Hypertrophic Arthritis of Spine. J. G., aged 57, a railroad brakeman, was thrown to the ground from a slowly moving train He apparently suffered no acute injury, but within the hour began to notice progressive advance of pain in the lumbar spine. Roentgenograms made upon his entrance to the Guthrie Clinic and the Robert Packer Hospital later the same day failed to show fracture of the spine or of the hypertrophic processes that bridged all of the lumbar vertebrae completely or in part. Physical examination revealed a level of exquisite tenderness in the midline and in the lateral muscle masses at the level of the spinous process of the second lumbar vertebrae. Injection of 10 cc. of 1 per cent novocaine was made into each lumbar muscle mass at this level. The patient was immediately relieved of pain but was kept recumbent in the hospital for ob-

servation He remained fairly comfortable for almost 24 hours, after which the pain gradually returned at the same level and at the same site He was then reinjected with the same solution and by the same technic Relief lasted this time for three days, following which he had slight residual soreness for four days This latter was not sufficient to interfere with his regular work It is to be noted that absolute bed rest was also employed for the first four days of this patient's stay in the hospital No support or physical therapy of any type was used

We have employed the injection technic in sternoclavicular sprain, sprain of the manubrium and xiphoid with and without dislocation, and costochondral sprain Relief is immediate no support such as adhesive strapping is necessary Indeed, the latter retards recovery when this method is used

LOW-BACK STRAIN (SPRAIN) SCIATICA AND OTHER REFERRED PAIN IN LOWER EXTREMITIES

> If we could just know where we are and whither we are tending we could better judge what to do and how to do it —A Lincoln

The above quotation is applicable in low back strain The therapy is usually clear as soon as the diagnosis becomes certain To completely discuss all the means of diagnosis and all of the therapeutic possibilities would be far beyond the scope of this chapter Full information upon these injuries will be found in Chapter 9, Low back Pain This complaint is as frequently encountered as any in medicine, and, by and large, in the hands of the average practitioner, is as unsatisfactorily treated as any single complaint Most patients with "low-back strain" have this symptom as an expression of a benign disorder of the spinal column and its surrounding ligaments and muscles, poor posture, arthritis, or ligamentous sprain Trauma and occupation play an important part in its pathogenesis In the past, acute back injuries, unaccompanied by fracture, have been described as ligamentous and muscular injuries This author believes the two to be inseparable

There is no routine treatment that can be applied to these patients, but a high percentage of them can be relieved by conservative means The patient presenting the symptom of low back pain after trauma, even though it be acute in origin, should receive an exhaustive analysis [See Chapter 9 —Ed] A careful history and physical examination will usually narrow down the causes of the patient s pain to two or three possibilities A rectal examination should never be omitted

Assuming that infectious causes and neoplastic disease (including spinal cord tumors) have been ruled out by the examinations described above, there remain a large number of patients who present this complaint and in whom the factors of posture, mechanical and rheumatic states and acute muscle or ligamentous sprain or strain are operative singly or more usually in varying degrees together The therapeutic management will include the following measures rest support, sedation, physical therapy, and local anesthesia for diagnostic and therapeutic purposes (Fig 974)

The recent prominence afforded the prolapsed intervertebral disk in the medical literature is out of proportion to the frequency with which it is actually found in persons with low back pain with sciatic and other pain radiating into the thigh It should always be kept in mind and confirmed by adequate intraspinal studies in persons whose discomfort does not readily yield to conservative measures

[The Editor would like to add his support to this statement, and to cite the support of Magnuson to the viewpoint The abandon with which many men label all sciatic pain, and even low back pain without sciatica, as "disk lesion" is hard to understand If the disk lesion is not found

at operation it is nevertheless considered as present, but failure to find it is explained by the statement that the lesion must have been a "concealed" one, not demonstrable. It is difficult to rationalize such an attitude. It would be a great comfort to the surgeon if he could take the same viewpoint toward chronic appendicitis, so-called. It would not be surprising if in future years the present attitude toward "disk lesions" should undergo the same sane revision of viewpoint that the old surgical attitude toward chronic appendicitis was subjected to.—Ed.]

So important is the use of immobilization and local anesthesia regarded in the treatment of these conditions in this clinic, that our methods and the reports of others upon which they are based will be described in detail. Steindler and Luck describe tender "trigger points" associated with pain low in the back (Fig. 975), located by physical examination and by the deep injection of 2 to 10 cc. of 1 per cent novocaine (smaller amount for fascial areas, larger amount for the joints). These findings are as applicable in acute back sprain as they are in chronic low-back pain.

By this method, pain is localized to the sacrospinalis area, the lumbosacral-joint area, to zones over the sacralized transverse processes (transversosacral syndrome), or to the aponeurosis of the iliotibial band Regardless of the seat of origin of the pain, any of the above conditions may give rise to sciatica of "reflex" origin. According to the statistics of Steindler, the results of treatment in which the reflex character of the sciatic pain was demonstrated were good in 84 per cent. The type of immobilization employed by him ranged from bed rest with traction, jackets, and braces to operations upon the aponeurotic and bony components of the low-back area.

Haldeman and Soto-Hall obtained immediate improvement from the injection of novocaine in 38 of 42 patients with pain localized to the sacro-iliac area (with and without sciatica); 25 of these patients also reported lasting benefit. Their beneficial effects were clouded by the fact that manipulation of the sacro-iliac joint was also carried out.

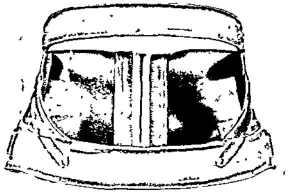


FIG. 974. Williams "chair-type" low-back brace

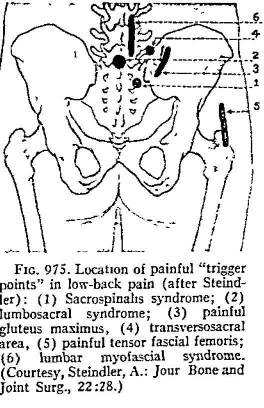


FIG. 975. Location of painful "trigger points" in low-back pain (after Steindler): (1) Sacrospinalis syndrome; (2) lumbosacral syndrome; (3) painful gluteus maximus, (4) transversosacral area, (5) painful tensor fascial femoris; (6) lumbar myofascial syndrome. (Courtesy, Steindler, A.: Jour Bone and Joint Surg., 22:28.)

The author and his associates have treated 116 patients (including patients presenting either chronic or acute back sprain, 63 with 1 per cent novocaine and 53 with the novocaine-eucupin solution previously described) with these disorders by

injecting local anesthetics into the painful areas discovered by careful palpation of the low back zone in relation to its joints These were all patients in whom organic disease of the bones of the low back area had been ruled out by roentgenograms and in some instances by the intraspinal use of air and/or lipiodol (myelography) Immediate relief was obtained in 93 per cent and significantly prolonged continued relief in 72 per cent One to three additional injections were necessary in about one third of these patients Support in the form of prolonged back strapping or a suitable low back brace was used as additional treatment in 15 per cent of the total number Roughly one third of the total number were advised to spend a variable number of days at total bed rest These in general were patients who were treated in the author s hospital practice He considers the method to be a definitely helpful auxiliary procedure in the treatment of these patients One of its chief advantages is that the patient can often be treated without entering the hospital It is no more universally applicable than any one other single method or appliance in the treatment of patients who have low back pain after trauma The author s most striking successes have been attained in persons presenting themselves with post traumatic back pain where no complicating disease or mental attitude was present No patient with continued low back pain should long be treated unsuccessfully by any of the more simple methods without exhaustive clinical investigation [For further discussion of low back pain see Chapter 9 —Ed]

INJURIES TO SHOULDER

A surgeon treating shoulder lesions should try in each individual case to picture in his mind the relative proportions of the elements of the joint which may be involved —E A CODMAN

Those who treat lesions in and about the shoulder should possess a thorough knowledge of the anatomic relations about this joint Knowing these the specific injury to the shoulder which may masquerade as a sprain can be correctly segregated and the appropriate treatment applied

The human shoulder is a universal joint surrounded by many ligamentous systems and muscle and tendinous attachments The ligaments are the coraco acromial the acromioclavicular and the coracoclavicular all are involved in the clinical acromioclavicular sprain and separation The anatomists coracohumeral and glenohumeral ligaments are portions of the joint capsule Just without the capsule which binds into approximation the humeral head and the scapular glenoid face is that conjoined insertion of the short rotators known as the musculotendinous cuff made up of the combined tendinous insertions of the subscapularis teres minor supraspinatus and infraspinatus muscles inserting into the tuberosities and the anatomic neck of the humerus The tendon of the long head of the biceps bears an important surgical relation to the upper humerus running through the bicipital groove through the latero superior wall of the capsule and then over the humeral head in an intracapsular course to insert on the upper margin of the glenoid These muscles and their tendinous attachments are all commonly subject to traumatic rupture or sprain

Shoulder sprains are not common inasmuch as most traumatic injuries in this region can be segregated into definite tendon dislocations or injuries However if after careful examination the pain and tenderness remain diffuse and roentgenograms fail to show bony injury the injury in question is a sprain of the shoulder The author does not favor the use of adhesive strapping for these injuries except in the aged and the infirm where there is a low pain threshold In all instances of trauma about the shoulder one has constantly to be on guard against the development of periarthritis and fixation or freezing of

the joint by adhesions If pain points can be delineated, they should be injected with novocaine or similar solution. The injection may be repeated in 48 hours if necessary. Since, as is usually the case, the pain and tenderness are usually diffusely distributed, the more appropriate treatment would consist of the application of radiant heat and massage, encouraging the patient to actively use the joint short of acute discomfort

Acromioclavicular Sprain with and without Separation

This lesion, which follows direct violence to the shoulders and which is commonly seen in football players in automobile injuries, and in other instances where direct violence is the mechanism of the injury, can be diagnosed only by physical examination when there is no gross separation of the bones involved. If gross separation of the involved bones is present, comparative views of both shoulders will show the difference between the two.

Treatment consists of adhesive strapping, preferably over a small felt pad, crisscrossing over the shoulder in such a manner as to prevent excess motion of the clavicle upon the shoulder girdle. After a week or ten days of such strapping, the shoulder is then relatively painless and the strapping can be removed. These patients tend to remain without subjective symptoms of pain although the space demonstrated between the bones remains permanently (Fig. 976).

Fig 976. Acromioclavicular sprain (*Left* and *Center*) During acute stage Compare separation of these two bones on injured side with the normal (*Right*) Three weeks later. Note that bony status is almost identical with that of left-hand illustration during acute stage. At this time patient was symptom-free

This is the "weak shoulder" of football players, prone to recurrent sprain after slight trauma In chronic and recurrent cases, an audible click often develops, produced by elevation of the shoulder. In some persons this is associated with pain and open operation is indicated, in which a strip of fascia lata is imbricated about the zone of approximation of the two bones. [Excision of the acromial end of the clavicle is an easier and a more certain procedure. See Chapter 29 —Ed] In the few cases where we have had the opportunity to apply the injection treatment into the ligaments about the joint, it has been found to relieve the pain just as in any other sprain

Sternoclavicular separation may also occur following direct trauma to the shoulder. This is a partial dislocation at the joint accompanied by a variable amount of ligamentous tear. These are ideal instances for the application of the injection treatment which is administered into the ligaments surrounding the joint. Following this, a long adhesive tape strapping, originating from over the top of the same shoulder and running diagonally over the opposite chest, is applied. Even though some prominence of the joint and slight instability remain in chronic cases, it is very seldom painful and, as a result, will require no treatment. [See also Chapter 29.—Ed.]

Periarthritis of Shoulder

Following definite trauma to the shoul-

der or following minimal trauma in the middle aged or merely from immobilization for sprain or fracture in any location in the upper extremity it is very common to observe a painful shoulder in which motion is three quarters or more restricted The roentgenogram is usually negative The joint appears frozen Since osseous grating is often noticed by the patient before stiffening and observed by the surgeon after successful mobilization of such shoulders it must be inferred that degenerative arthritis (osteo arthritis) is present in some of these shoulders Osteophytes do not develop in the shoulder since there are no *osteo cartilaginous junctions within the* joint capsule Adhesions within the subdeltoid bursa have been demonstrated at operation

The treatment preferred by the author is careful manipulation under general anesthesia through all possible ranges of motion followed by massive hot moist packs and analgesic drugs to relieve pain with daily supervised periods of active and passive motion of the joint During the active period of treatment the patient remains in bed with the arm anchored in abduction and external rotation by a tie to the head of the bed It is left free for a total of only four hours a day exclusive of the supervised periods

In the author s opinion the above method is less painful than the method of gradual extension by traction and less time consuming tedious and expensive to the patient than mobilizing such a joint by gentle passive and active motion without anesthesia over a long period of time While a fair range of motion (75 per cent of normal) is obtained by the method described above in four to seven days after manipulation the patient must then carry on a faithful regimen of exercises for 15 minutes three or four times a day at home to preserve motion and to gain a full range of painless motion These exercises consist in wall climbing exercises in which the patient faces the wall places the palm of the hand against it with the elbow flexed gradually elevating the shoulder by upward motion Passive external rotation is achieved by pushing the shoulder farther against the wall Active rotation exercises with the patient standing flexed at the hips i e looking at the floor are of value as are also exercises taken rotating a large well balanced wheel through its circumference [See Chapters 15 and 29 —Ed]

The author has treated cases of periarthritis of the shoulder by manipulation under sodium pentothal anesthesia A satisfactory end result range of motion (less than *10° restriction from normal motion* in any plane being free and painless) was obtained in 82 per cent Some of the best end results at the three month period have been obtained in cases that had only a fair result after three or four weeks

INJURIES TO ELBOW

> The toll of deformities and disabilities they [njuries to the elbow] have levied in the past have won a reputation for form dablene s that is scarcely equaled
> —P D WILSON

If roentgenograms are taken following injury to the elbow it will be found in many cases that marginal or impacted fractures are present in this region In these cases physical examination does not aid too much in the diagnosis as the patient is often able to move the joint through almost a normal range of guarded motion Physical examination though should be carried out carefully and as accurate location of the tenderness about the normal bony prominences of the elbow as possible noted External wounds and abrasions should be diagrammed An important point in the examination of the elbow is that the two humeral epicondyles and the tip of the olecranon process of the ulna should be in the same horizontal plane when the elbow is extended [See Chapter 31 for further anatomical details —Ed]

Epicondylar Marginal Fractures Considered as Sprains

The ossific centers of the humeral epicondyles appear between the sixth and thirteenth years (later in the lateral epi-

Fig. 977. Illustrative cases of fracture-separation or sprain of mesial humeral epicondyle: (*Left*) Case in child of ten years. (*Right*) Case in boy of 17 years.

condyle), and unite to the shaft between the fifteenth and seventeenth years. Between the time of the appearance of the center and its union to the shaft, injuries may separate this center of ossification through the cartilage line that joins it to the humerus Following this time, chip fractures often split through the old site of the last remaining cartilage line In adolescents and young adults, separations or fractures of the epicondyles frequently do not unite by bony union to the shaft even though immobilization be maintained for a prolonged period (Fig. 977).

The diagnosis is established by localized tenderness and swelling followed by the characteristic roentgenographic appearance. If displacement is only slight, these fractures can be treated by immediate mobilization following injection of local anesthetic, cautioning the patient to be certain that no abnormal violence occurs to the elbow within the ensuing six to ten weeks. Heavy labor is forbidden. These injuries become painless after one or two injections of local anesthetic and use of the arm, similar to the behavior of sprains. Due to the difference in blood supply, the mesial humeral epicondyle is particularly likely to be united to the shaft by only fibrous union. It has yet to be determined whether any prolonged period of immobilization will yield higher percentages of bony unions in this fracture *and its concomitant musculoligamentous tear*, or whether union is solely a question of adequacy of blood supply. [The Editor would like to subscribe to this viewpoint. It is his feeling that fracture or separation of the internal epicondyle is one of the most overtreated lesions commonly seen.—Ed.]

Partial Rupture and Tear of Orbicular Ligament Unassociated with Dislocation of Radial Head

Another point in the examination of the elbow which should be specifically searched for, especially when little or no injury is evident in the roentgenograms and on phys-

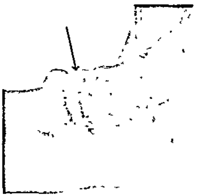


Fig. 978. Case of impacted fracture of radial head and fracture of coronoid process of ulna. This patient had 75 per cent of a normal range of painless motion in the acute stage. Arrow points to coronoid process. (See also Fig. 966.)

ical examination, is the position of the head of the radius, both in supination-pronation and in acute flexion and extension. The orbicular ligament will occasionally be torn, which diagnosis can be inferred from local tenderness and inflammatory signs, with or

without subluxation of the radial head superiorly or posterolaterally Pain can be relieved by injection or by immobilization in splint or circular plaster movement being started as soon as comfort will allow aided if necessary by further injections

Chip Fracture of Olecranon and Coronoid Process of Ulna

These fractures also frequently masquerade as sprains There is every gradation from a purely ligamentous injury with or without shearing off of a bony plate to avulsion of a larger bony fragment (see Fig 978) Usually fragments from the coronoid process and olecranon are not markedly displaced as they are held in position by periosteum and tendon attachments the best treatment is immobilization in a posterior splint in the first instance in flexion beyond 90° and in the second instance in extension beyond 90° in the position that is most comfortable to the patient Immobilization should be maintained for two weeks following which time the joint should be rapidly mobilized If pain then ensues mobilization should be continued aided by injections of local anesthetic Roentgenograms should follow this latter step since on rare occasions healing of the bony fragment is not complete and exercise causes it to separate This however is exceptional and should be treated by two to three weeks' additional immobilization if it occurs

INJURIES AND DISORDERS OF WRIST, HAND AND FINGERS

The human hand is one of the higher evolutionary developments of our biped existence, which is largely responsible for the great handicraft of man It includes exact machinery of much refinement and tissue of great delicacy and specialization —Sterling Bunnell

Wrist Sprain

The same types of trauma that produce fracture at the wrist often fail to injure bone and ligamentous tear results The external appearance of the more severe wrist sprain differs little from fractures in this zone especially fractures of the carpus nondisplaced fractures of the radius and those involving the styloid processes of the radius and ulna Exact diagnosis is established by the roentgenogram Wrist sprain is rare in comparison to the numbers of cases of actual bone injury in this region Most wrist sprains are seen in children and adolescents the age when wrist fractures are rare

If the sprain is of sufficient degree to be moderately or acutely painful or if marked swelling is present this injury should receive as much attention as a fracture in the area There are two means of treatment either of which effectively relieves the patient Since these two means of treatment are opposite in principle election should be made at the time the patient is first seen One method employs immobilization This should be effected by a skin tight unpadded plaster encasement covering the forearm and the hand so trimmed that free active motion is possible in the thumb and at the metacarpophalangeal joints The wrist is placed either in slight palmar flexion or in slight dorsal flexion whichever is most comfortable to the patient As soon as the plaster is set trimmed and dried somewhat the patient begins active use of the thumb and fingers within pain limits The plaster is allowed to remain in place for two weeks and is followed by progressive active use

The other method utilizes active motion from the onset following aspiration of the hematoma if present and injection of the local anesthetic into the ligaments In this method injection often has to be done again and a certain degree of morning discomfort and stiffness is observed for four or five days For an illustrative case history see Case 1 p 1141

If pain and discomfort persist beyond two weeks the patient should be re-examined by the roentgen ray It is then usually found

that a fracture of the scaphoid or a small *marginal fracture of the radius is present,* this being invisible at the time of the initial examination due to absence of displacement. Baking and diathermy are contraindicated in wrist sprains because of the frequency with which pain is made more severe by their use.

The lower radio-ulnar ligament or triangular ligament (discus articularis) is occasionally torn. This structure is unique in stabilizing this joint in any position The signs of the injury are ioint hypermobility in anterior and posterior directions on passive pronation and supination, and abnormal palmar displacement of the ulnar head *after the injection of a local anesthetic.* It is seen with regularity only with chip fractures at the base of the ulnar styloid, or those involving the ulnar border of the distal radius, or in severely comminuted fractures of the distal radius with shearing of the ulnar styloid at its base. The diagnosis of this injury, in the absence of fracture or with the marginal fractures mentioned, is of importance since, when overlooked and the wrist is not immobilized for a sufficiently prolonged period (five or six weeks), widening and permanent transverse laxity of the wrist occurs, which may be permanently painful.

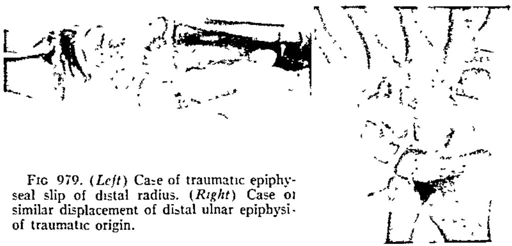


Fig 979. (*Left*) Case of traumatic epiphyseal slip of distal radius. (*Right*) Case of similar displacement of distal ulnar epiphysis of traumatic origin.

[Pure sprains of the inferior radio-ulnar joint are not uncommon without any accompanying fracture. *They are to be suspected* when the maximum tenderness is over the inferior radio-ulnar joint rather than over the carpus, and where the most painful motion is that of rotation. They respond well to the use of local anesthesia and active motion. After all acute signs have disappeared a snug wristlet or laced wristband will aid the return of function in those who do heavy work.—Ed]

Contusion to the bones of the wrist should be differentiated from wrist sprain (a purely ligamentous injury) by the location of pain and perhaps by identification of the initial point of impact of the injury. In wrist injuries, the following conditions have to be considered (in addition to those already named):

- Posterior dislocation of wrist without fracture.
- Fracture of distal radius with or without separation of ulnar styloid with dorsal displacement (Colles's fracture).
- Same fracture with palmar displacement (reverse Colles's fracture, more rare).
- Traumatic separation of distal ulnar or radial epiphysis.
- Both bone fractures in lower third.
- Fractures of radial or palmar styloid.
- Fracture or fracture-dislocation of scaphoid and other bones of carpus.

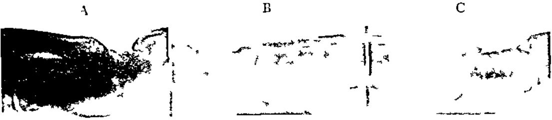
- Dislocation of lunate
- Traumatic tenosynovitis of tendons about radial styloid
- Post traumatic osteoporosis of carpus
- Fractures and fracture dislocations at base of first metacarpal, including Bennett s fracture

The treatment of the fractures just listed will be discussed in other sections of this volume Epiphyseal separation is encountered with frequency In any clinic where a fair proportion of the patients are juveniles and adolescents about one sixth of all the wrist injuries will be found to be epiphyseal separations about half of those seen in the young are this injury If this is kept in mind and it is recognized that it may occur with a variable amount of metaphyseal bone being carried with the displaced distal fragment, it will be recognized in roentgenograms (Fig 979)

[The diagnosis of sprain in a child should be made with caution Many so called sprains in children are epiphyseal traumata without actual displacement, completely undemonstrable by x ray Nevertheless a certain percentage of these cases are followed by growth disturbance See Chapter 22 for a general discussion of epiphyseal traumata —Ed]

Injuries and Dislocations of Small Bones of Wrist

This subject will not be discussed in extenso in this place because it will be adequately covered in other chapters of this work dealing with these fractures Their relation to wrist sprains is an intimate one, chiefly because the fractures and dislocations were often overlooked in years past due to the lack of adequate roentgen plates At present the chief danger is that they are overlooked by the unwary when another major wrist injury is present (Figs 980 981) Lateral views are diagnostic of dislocation of the lunate As mentioned previously, one of the chief causes of persistent pain in the wrist is an unrecognized fracture of the carpal scaphoid The other bones of the wrist are fractured so infrequently



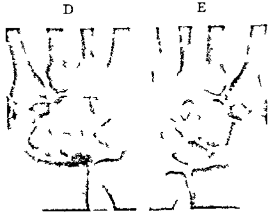


Fig 980 (A) Case showing small chip fracture at base of first metacarpal

(B) (C D and E) Anteroposterior and lateral views of wrists of a man who had sustained bilateral fractures of distal cancellous radius but in whom bilateral carpal injuries had been completely overlooked by first surgeon These carpal injuries consist of (C) and (E) a fracture across waist of navicular and (B) and (D) an almost complete dislocation of semilunar Note diagnostic lateral view of latter injury (Courtesy, Division of Roentgenology of the University of Chicago Clinics)

that they need not be discussed in this place. Several anteroposterior views of the wrist should be made in varying degrees of ulnar and radial deviation in cases of suspected fracture of the scaphoid, as the maneuver will often demonstrate a fracture line hidden in the neutral positions of the wrist. [See injuries to the carpus, Chapter 33.—Ed.]

Injuries to Fingers

Most finger injuries are due to the impact of direct trauma to the finger ends, since a crushing injury and direct severe violence from the sides results in fracture of one or more of the phalanges. As in other injuries, a roentgenogram should always be taken because fractures will be discovered with frequency. Although not ordinarily disabling, the finger injuries to be described are followed by stiffness and increasing disability if neglected.

Dislocations at the interphalangeal joints are not uncommon due to the relative ease of tear of the interphalangeal joint capsule. They should be mobilized soon (seven days) after replacement and early immobilization so as to avoid permanent stiffness of the joint. If sufficient capsular tear occurs, the nutrition of the epiphysis is disturbed and aseptic necrosis results (see Fig. 969 E). This is never a serious complication as the forces brought to bear upon such an epiphysis are never sufficient to crush it and replacement by living bone proceeds without complication.

Trauma without production of any of these deformities, and with pain only (sprain), is never sufficiently disabling in this author's opinion to warrant the injection of local anesthesia in the finger alone. The patient is instructed to continue its use, with the aid of hot soaks, and perhaps a night splint. Pain is usually gone in two or three days.

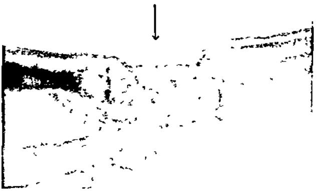


Fig. 981. Cases of wrist disability without obvious traumatic origin, but which presented a history of trauma. (*Left*) Case of Kienböck's malacia of lunate. (*Right*) Case demonstrating calcification in tendon sheaths of extensor *tendons of hand indicated by arrow.*

INJURIES AND DISORDERS OF HIP

> Life begins within the pelvis but often passes out through the hip joint.—Oliver Wendell Holmes.

A hip sprain is seen infrequently. The patient who usually presents himself with the complaint of a chronic painful hip will, on examination, usually be found to have a painful low back. The diagnosis and treatment of these conditions has been previously discussed.

If, after physical examination, the disorder appears to be localized to the hip,

stereoroentgenograms should be made of the pelvis The earliest abnormal physical finding of disease of the hip is loss of passive circumduction The slightest irregularities in the joint or muscle spasm about this joint will produce this sign It is best elicited with the patient lying flat on his back In more severe instances passive flexion adduction and abduction are lost in proportion to the severity of muscle spasm or duration of seriousness of bone abnormalities about the hip Most instances of hip pain usually reveal enough alterations in the roentgenogram to diagnose disease at this joint The following should always be considered solitary or multiple chronic arthritis involving this joint senile hypertrophic arthritis (coxa malum senilis) chronic pyogenic arthritis chronic tuberculous arthritis juvenile aseptic necrosis slipped upper femoral epiphysis (preslipping and after the change has occurred) The exact roentgen diagnosis of these conditions is described elsewhere Roentgenograms of two instances of these disorders are reproduced in Fig 982

A disorder known as snapping hip is occasionally seen which may give rise to the symptoms of chronic sprain about the hip It is usually due to the iliotibial band or tensor fascia femoris muscle sliding over a protuberance such as the greater tuberosity of the femur The treatment of this condition is described elsewhere

INJURIES ABOUT KNEE INCLUDING EXTENSOR APPARATUS

When a patient complains that his knee slips catches locks or gives way it is no longer wise to make a diagnosis of a loose meniscus and take it out through a peep hole incision —WILLIAM DARRACH

INJURY TO LIGAMENTS OF KNEE

These injuries (Figs 983 and 984) are usually sustained during violent exercise particularly during football and basketball games Other injuries about the knee usually result in fracture or in dislocation of one of the semilunar cartilages Violent trauma with twisting or hyperextension usually results in rupture of one or more of the lateral ligaments or injury to the cruciate ligaments It is noteworthy that these latter ligaments are not necessary for stability except when the knee is in flexion Their function appears to be that of limiting the extremes of extension and flexion and stabilizing the knee in flexion In certain instances loss of the cruciate ligaments results in distortion of anteroposterior gliding of the femoral condyles which takes

FIG 982 Two instances of patients whose disability about hip is unidentifiable unless roentgenograms are taken (*Left*) Case of slipped upper femoral epiphysis (*Right*) Case of bilateral aseptic necrosis of femoral head of unknown causation in an adolescent

place on the tibial condyle in flexion. Many times it is necessary to inject local anesthesia into the painful spots about the knee or examine the patient under general anesthesia in order to establish a certain diagnosis of rupture of one of the ligaments mentioned.

The sign of lateral-ligament rupture is instability of the knee in extension while the sign of cruciate rupture is excessive anterioposterior mobility in flexion. In certain instances the tibial spines are carried along with the avulsed ligaments. Such an injury can be recognized in the roentgenograms. The treatment of rupture of the ligaments mentioned is application of a long leg cast including the foot for a minimum period of eight weeks. Sprains about the joint are difficult to differentiate from lateral-ligament tear. The diagnosis should never be made until after anesthetization. For this latter reason an excellent preliminary in the diagnosis *can also be used therapeutically* in the treatment if injury proves to be only one of sprain. The case history of a knee sprain including lateral-ligament sprain is reproduced on p. 1142. If, after removal of cast and treatment of ligamentous injuries, instability is still present, surgical repair of the lateral or cruciate ligaments should be undertaken. This can be performed in various ways by the use of free or pedicled transplants of fascia lata. [See Internal Derangement of Knee Joint, in Chapter 38 for a discussion of this and other articular derangements.—Ed.]

Traumatic Hemarthrosis and Recurrent Hydrarthrosis

Fluid may appear in the knee joint following any type of injury with or without ligamentous tear. It is common to see an accumulation of fluid in this joint following

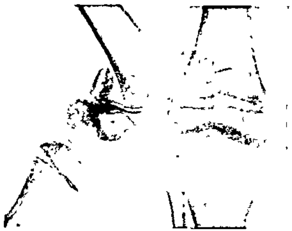


Fig 983. Case demonstrating slipped proximal femoral epiphysis of traumatic *origin.*

any sprain or a trivial injury This fluid may be bloody, blood-tinged, or yellowish and clear If distension is enough to cause the patient to complain of it, the fluid content should be aspirated through a large-bored needle. *This can be conveniently done* under local anesthesia, but strictly aseptic precautions must be observed The knee should be prepared several hours previous to the aspiration, by as rigorous a technic as for a patient who will undergo a major operation. Following aspiration, the patient

Fig. 984. Anteroposterior roentgenograms of four cases of depressed fracture of tibial condyles.

should be ambulatory only with crutches, and should bear no weight for from one to two days on the leg The knee should be supported by a tight elastic stocking or one or more three inch elastic bandages [See Chapters 15 37 and 38 for knee joint aspiration —Ed]

INJURIES TO SEMILUNAR CARTILAGES

This is one of the commonest knee joint injuries except that of simple sprain and it may closely simulate pure sprain In the classic case there is a history of acute locking of the joint following the injury The flexed position in which it is locked will be maintained for a variable period of time It is now recognized that the classic signs of locking are not necessarily present in all semilunar cartilage injuries particularly in the type of longitudinal tear of the ligament with central displacement of the peripheral fragment — so called bucket handle tear of the meniscus

INJURIES TO ANKLE

It is worse to sprain an ankle than to break it —R WATSON JONES

Ankle injury is the most frequently encountered sprain If not properly treated it may lead to the greatest disability Three degrees of sprain of the ankle should be distinguished (1) Stretch or slight tear of the fibers of either mesial or lateral ligament of the ankle, usually the latter, (2) severe tear of the lateral ligaments with posterior and mesial inversion of the astragalus on the tibia, (3) either of the first two injuries accompanied by tibiofibular separation These degrees of sprain can be distinguished at times in routine roentgenograms but if spontaneous reposition of the astragalus occurs as is frequently the case, swelling and muscle spasm will prevent easy redislocation when an attempt is made to demonstrate the ankle click Likewise, these are instances of tibiofibular ligament laceration with minimal separation that do not show in the roentgenogram

The only certain means of making an exact diagnosis of the type of ankle sprain is by the injection of local anesthetics into the painful area and into the anterior joint capsule area (for the tibiofibular ligaments) as part of the diagnostic procedure

After anesthetization of these areas the foot is tilted strongly into inversion If lateral motion of the astragalus is demonstrated on the tibia and an ankle click is elicited, then it is certain that the tibio astragalar ligaments have been torn

The roentgenogram can be used to confirm these findings To demonstrate lateral tibio astragalar ligament tear the view must be taken in inversion and for medial tibio astragalar ligament tear in eversion In tear of the tibiofibular ligament the ankle mortise is widened, the astragalus is unduly loose in it and actual separation of the tibia and fibula can often be demonstrated on pushing the astragalus outward against the fibula

[The use of these diagnostic procedures under local anesthesia in all except the mild ankle joint sprains is certainly very worth while Too many severe sprains are under treated with resultant chronic instability Too many mild sprains are overtreated with unduly prolonged convalescence and disability time Demonstrable instability should be the criterion which labels a sprain as severe—not the degree of ecchymosis or swelling which is present

Ankle sprains involving the collateral ligaments should not give severe tenderness over the inferior tibiofibular joint This should be looked for in all ankle joint sprains, and if found is strongly suggestive of tear of the inferior tibiofibular ligaments

These instabilities are far more frequent than is generally recognized and the procedures here advised are frequently the only means by which they can be diagnosed —Ed]

If ligaments are torn sufficiently to allow luxation of the astragalus out of the mortise, the presence of a serious injury is

demonstrated. This injury, with or without inferior tibiofibular-ligamentous tear, must be immobilized for at least six weeks in a skin-tight plaster boot. In severe grades of tear, the immobilization should be for eight weeks. Following such prolonged treatment, recurrent sprains should no longer occur. These recurrent sprains are due to redisplacement of the astragalus due to inadequately healed ligament tears or to instability of the tibiofibular mortise, due to tear of the corresponding ligament.

Simple sprains should be treated by the injection of 10 to 15 cc. of 1 per cent novocaine or of novocaine solution containing 0.1 per cent eucupin, into the painful area with immediate weight-bearing. The swelling in the middle-aged and the aged can be controlled by an elastic bandage. If the person is not suited for the injection treatment, being by temperament timid and apprehensive, he should be treated by the *elastic strapping method,* by wrapping the joint with many thicknesses of elastic bandage, and prohibition of weight-bearing for from five to ten days, during which time he can be ambulatory only with crutches.

[Simple sprains of the collateral ligaments can be strapped adequately by moleskin adhesive as follows:

1. A loop of gauze bandage is placed about the great toe, and the patient holds the two ends to keep the foot at right angles with the leg and in weight-bearing position of inversion, with the knee flexed.

2. A two-inch strip of moleskin adhesive is placed on the outer side of the leg at the junction of the upper and middle thirds, the skin having first been shaved and coated with tincture of benzoin.

3. Downward traction is made on this strip until all the "give" of the skin on the deeper tissues is taken up.

4. With traction steadily maintained on the adhesive strip it is carried underneath the plantar surface of the arch and to the inner side of the foot.

5. The skin on the inner aspect of the leg is pulled down, and the adhesive strip, still under traction, is attached to the taut skin at the junction of the upper and middle thirds of the inner surface of the leg.

6. A single strip of adhesive is used to *anchor the upper ends of the strap, not completely* encircling the leg.

7. 3-inch elastic bandage is applied from the toes to the upper limits of the adhesive.

The patient is not allowed to bear weight for 24 hours, but after that time can use a cane, or can go without such support if there is not too much discomfort on weight-bearing. If the upper ends of the adhesive show signs of slipping, another similar strap can be applied over the old one to take up any slack. From 5 to 10 days of such strapping is usually adequate. An elastic bandage is worn as long as any swelling remains.—Ed.]

For the average and routine case, the injection treatment is preferred by the author. *Elderly or debilitated patients should never* be allowed to remain in bed after such a trivial injury because of the danger of thrombophlebitis, postfixation lymphedema, and many more severe complications.

In recurrent ankle sprains which present themselves for the first time to the examiner, the radiographic diagnosis can be made usually by inverting or everting the foot since the tear is no longer painful. The same roentgen signs are found as above. In recurrent ankle sprain due to unhealed tibiofibular-ligament tear, the widened tibiofibular joint can be invariably demonstrated. If the patient desires complete relief from the danger of recurrent sprain and to be relieved of the necessity of wearing ankle support constantly, he will have to submit to operative repair of the torn astragalar ligaments. In the case of chronic tibiofibular separation, an arthrodesis of the joint can be easily performed by a tibial-graft peg driven through a previously prepared drill hole which crosses the joint. Immobilization should follow in a skin-tight plaster for ten weeks.

[There is definite objection to fusion of the inferior tibiofibular joint It has been shown that full dorsiflexion is accomplished by upward movement of the fibula at this joint as the anterior wide part of the

FIG 985 Cases of chip fracture about ankle treated by excision of free fragments and operative repair of ligaments

(*Left*) Anteroposterior view of case seen after being treated elsewhere as a sprain without benefit of roentgen diagnosis It was treated by open operation by excision of the free mesial malleolar fragment performing an osteotomy through callus of fibular fracture and inserting a bone peg removed from lower tibial shaft through a drill hole placed from fibular side through inferior tibiofibular joint in order to treat tibiofibular separation followed by immobilization in a skin tight cast for six weeks Excision of mesial malleolar fragment did not interfere with subsequent ankle stability and simplified ligament repair on this side of ankle

(*Right*) Case in which the only procedure applied was excision of the free fragment and local ligamentous repair

astragalus comes up between the tibia and fibula In cases where this joint has been made rigid as by bolting limitation of the full dorsiflexion (which is necessary in negotiating stairs and inclines) has been bothersome and in many cases the bolts have had to be removed ultimately It would seem preferable in these cases to clear out the inferior tibiofibular joint, approximate the joint surfaces by bolting and to remove the bolt after a period of three or four months when the new formed ligaments have become strong (see Chapter 22) Some men prefer arthrodesis of the ankle joint under these circumstances (see Chapter 15) —Ed]

Reconstruction of the lateral or mesial ligament can be performed with a twisted strip of fascia lata passed at least twice through drill holes in the malleolus and through a superior inferiorly placed drill hole in the astragalus On the lateral side of the foot the tendon of the peroneus brevis can be substituted for a free strip of fascia lata The surgeon should not hesitate to apply these procedures when the indications exist

Chip Fracture of Malleoli and of Lateral Surface of Astragalus

These fractures are merely sprains where in addition a bony chip has been avulsed at the time of ligamentous shear As such they are more closely related to the complicated sprains with ligamentous tear than to ankle fractures All gradations of injury occur When a small bony chip less than 2 mm in diameter has been avulsed it can be ignored as it will be absorbed Chips larger than 3 or 4 mm up to half the size of the malleolus should be excised under local anesthesia with direct repair of the ligaments with fine chromic catgut By this means ligamentous to bone healing is substituted for longer bone to bone healing Since the ligaments have been accurately re approximated by suture the time of immobilization with skin tight plaster can be cut to two weeks unless accompanied by inferior tibiofibular ligament tear (See Fig 985 for illustrative cases treated in this way) The total time of disability of such cases is halved by excision of the free fragment The incidence of chip fractures from the sides of the astragalus is greater than is usually thought Exact interpretation of roentgenograms must be obtained

Contraindications to excision of such fragments are: (1) Free fragment larger than half the malleolus; its removal would interfere with ankle stability, and it should be treated as a fracture. (2) Bilateral malleolar fracture; here the total time of immobilization would not be reduced by excision. (3) Small fragments less than 2 mm. in diameter, which will be eventually absorbed.

Continued Ankle Pain Following Sprains and Ankle Fractures

Accurate diagnosis of the type of ankle sprains and anatomic reduction of ankle-joint fractures should result in fewer patients presenting themselves with prolonged pain following these injuries. Most persons who have such continued pain are of middle or advanced age. The leading causes for prolonged pain are:

- Arthritis from maladapted joint surfaces, which includes fracture involving joint where active or passive motion was not begun early.
- Arthritis following traumatic injury of articular cartilages.
- Arthritis associated with aseptic necrosis of bone neighboring upon joint.
- Circulatory disturbance due to independent arterial vascular disease
- Postimmobilization lymphedema.
- Adhesion formation in ligaments and joint capsule.
- Acute post-traumatic bone atrophy (Sudek).
- Presence of free or partially united fracture fragments within or neighboring upon a joint.

When a patient presents himself with these symptoms, a careful physical examination of the ankle should be performed, the status of the circulation noted, and roentgenograms of the joint made. Aseptic necrosis of bone, bone atrophy, free fragments, and maladapted joint surfaces are then discovered. The latter two conditions, in the presence of persistent pain, are best treated by surgical methods, the first by excision of the fragment and the second by arthrodesis of the involved joint.

In aseptic necrosis, weight-bearing should be prevented until subsequent roentgenograms show that substitution by living bone has occurred; this is usually a matter of several months. Lymphedema should be treated by elevation of the leg, followed by support to the soft tissues, either by a paste boot or by elastic bandages applied to the entire foot and leg. It is sometimes necessary to continue this support in obstinate cases for from six to nine months Soft-tissue adhesions and stiffness, associated with pain, are treated by the usual baking with radiant heat, massage and active and passive motion.

If little progress is seen in the patient in a week or ten days of daily treatment, injection of novocaine into the painful area should be performed, following which the patient can walk for a variable time without pain. Relief often lasts for from several days to a week, or may be permanent. The author has occasionally employed novocaine injections followed by active walking as soon as the latter diagnosis was made

[See Chapter 22 for Sudek's atrophy — Ed.]

INJURIES TO FOOT

> Aching pain in the foot is often attributed to "flatfoot" and treated by strapping or the fitting of metal supports. Treatment by "supporting the dropped arch," immobilizing the joints, and forcing the foot to a predetermined shape is wrong.—R. Watson-Jones.

Chip Fracture of Bones of Foot; March Fracture of Metatarsals

The chip fracture of the bones of the foot encountered most frequently is that from the lateral side of the astragalus. This injury has already been discussed under ankle-joint disorders above Free osseous fragments occur with regularity in trauma to the navicular, cuboid, and the cuneiforms.

It is less necessary to excise such fragments as joint stability does not depend upon union of ligaments attached to their free surface as in the instance of astragalar and malleolar fragments Recovery is hastened if such free fragments are excised This can be done under local anesthesia

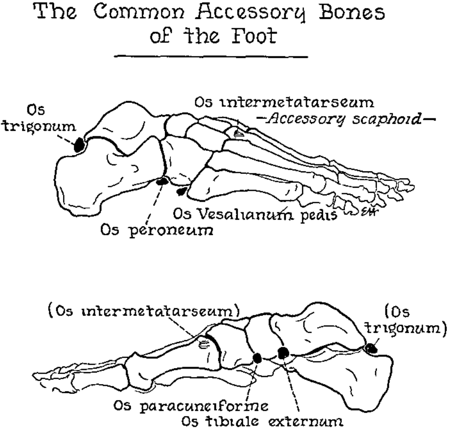


Fig 986 Location of accessory ossicles of feet

Usually a skin tight plaster boot with a walking iron should be applied as in this way the accumulation of edema fluid can be prevented and the patient can be ambulatory during the time required for healing The length of immobilization depends upon the extensiveness of ligamentous repair needed If extensive the boot should be worn for four weeks if only slight two weeks Free fragments should not be excised from the articular or shaft margins of the metatarsals or phalanges as these always unite and the disability following excision is greater than if they are treated conservatively When such free fragments neighbor upon a joint early passive motion (at the end of seven days) should be begun Marginal fractures occurring with insignificant or no known trauma should be suspected of having a luetic connection Physical examination of the reflexes and serology will confirm or eliminate such a possibility

A rare but painful injury is the fracture of the midshaft region of one or more metatarsals which is at first insignificant or invisible in the roentgenograms This injury occurs often in soldiers and others who walk long distances when not in the best of physical shape This is the origin of the name 'march fracture which is attached to the injury Since no changes are present in the

genogram early, the usual assumption ıde that the patient has a "foot strain." s usually then treated by ankle strap- but the pain continues. In a week or weeks after onset of pain, a roentgeno- shows a spindle-shaped subperiosteal fication (see Fig. 967) at the site of steal stripping about the fracture The cion of a malignancy is occasionally tained by those to whom the injury is miliar. In doubtful cases, and in typical nces as well, the treatment is three s' immobilization in a skin-tight plas- oot. A re-examination by the roentgen it the end of this period after removal ie plaster will confirm or clarify the nosis. [See also Chapter 40. In the ent world conflict "march" or "fatigue n" fractures have been noted in the , in the shaft of the femur and in the ral neck.—Ed.]

Accessory Ossicles of Feet

connection with marginal fractures acute foot strains, it is necessary to v the location and appearance of the ssory bones of the foot that are fre- ıtly visualized in roentgenograms and h usually have little connection with painful foot disorders. They are often neously taken to be marginal fractures. 986 shows their location. The most mon ones are the *os trigonum* and the ibiale externum. This latter accessory cle exists in every variation from a ninent mesial tubercle of the scaphoid separate ossicle 5 mm. in diameter. It is uently painful in children and adoles- s with flatfeet in whom the prominence ccentuated by mesial rotation of the hoid. The treatment is to cut down the ial shoe border so that pressure is re- ed from the prominence. If this does not ice, then surgical excision of this acces- bone should be carried out, with atten- to the fibers of the tibialis posterior ch may insert solely into the accessory cle.

Foot Strain and Flatfeet as Related to Acutely Painful Feet Following Trauma or Occurring in Treatment of a Traumatic Disorder

The subject of painful feet cannot be fully discussed in a short work of this scope. For further details and information the reader is referred to the recent monographs of Lewin and Hauser upon this subject and to Chapter 5. Longitudinal arch pain should be carefully differentiated from transverse arch pain. The indication for shoe corrections should be pain rather than anatomic features in adults. The best longitudinal arch support is a removable sponge-rubber or felt support covered with leather, manufactured for each individual patient. If anterior arch pain is present a metatarsal elevation can be included in the same support. Metatarsal pain alone is treated by combinations of metatarsal buttons and leather anterior metatarsal bars on the shoes. The choice of corrections depends somewhat upon experience and the patient. Authorities likewise differ as to whether stiff- or soft-shank shoes should be the basis of corrections. In general, in relaxed feet, stiff-shank shoes are preferred while malleable-shank oxfords are best for painful feet that are not too much relaxed. Contrast foot baths, baking and massage and the tepid whirlpool bath will be useful in relieving pain The physician who treats these conditions will find it useful to prepare printed instructions for his patients.

Persons who suffer from painful feet do not do so because of structural abnormalities alone. It is highly probable that there is a certain amount of "arthritis," interpreted in the broad sense, in the small joints of the feet of such persons. This is further attested by the success of those irregular practitioners, known as bone setters, who treat these conditions by manipulation of the feet. The frequency of relief should alone recommend this procedure. There are

many groups of patients that benefit from it persons who have had prolonged plaster immobilization following fracture or severe sprain persons who follow sedentary occupations the middle aged and the aged and those who have demonstrable but mild osteo arthritic changes in the bones of the feet If pain is well localized the preliminary injection of novocaine into the painful zone is advantageous If the extremity is very painful the manipulation is best done under general anesthesia The forefoot should be powerfully adducted and then dorsiflexed and the heel inverted Following this physical therapy is administered to relieve any residual soreness and weight bearing is begun at once in suitably corrected shoes if these are indicated

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42

Injuries to Muscle and Tendon Except in Hand

Clay Ray Murray, M.D.

GENERAL CONSIDERATIONS

The treatment for injuries to muscles and tendons is directed (1) to restoring continuity and normal length if they have been lost, (2) to minimizing the amount of hemorrhage and exudate which becomes organized in the structures so that there will be a minimal amount of thickening and scarring, and (3) to restoring normal-powered, smooth and coordinated muscle action as rapidly and as completely as possible. The methods used must meet these criteria if they are to be sound, and, as is the case in the treatment of sprains (see Chapter 41), prolonged convalescence often can be avoided if these criteria are kept in mind in administering treatment.

Apart from the operative procedures involved in the event of actual rupture, tear, laceration, or avulsion, generalizations can be made in reference to treatment methods for this "motor mechanism" of the skeletal system. These, however, must be regarded only as generally or usually true, and not as therapeutic "rules." The ability to recognize the indications for violating a so-called general principle in treatment of any condition is a major factor in intelligent therapeusis. It constitutes understanding of the difference between a principle and a rule, and leads to treatment properly adapted to the individual case.

Grasp of the following basic general principles is of practical importance in dealing with all disturbances of the gross physiology of this system, whether associated with injury or not.

1. Rest as a therapeutic measure is to be interpreted in terms of avoidance of pain, spasm, fatigue, and undue strain on the healing tissue rather than as complete immobilization. It is too generally interpreted to mean the latter, so that complete abolition of function and rest come to be regarded as synonymous terms. This interpretation is not only illogical, but the results may be definitely deleterious. One might just as rightly regard induced coma as the only means of meeting the indication for rest in a patient. We are careful to distinguish between relaxation, normal sleep, sedation, and narcosis in considering rest for a patient, and we should be just as careful to distinguish between degrees and durations of rest for the muscular system, using the above criterion as our guide. That this is not mere sententiousness is rather graphically, and frequently tragically, illustrated in the common handling of back injuries in which muscle-fiber tears — "strains" — or musculotendinous insertion tears—"sprains" —are the predominant lesion. The sound principle that "rest" is beneficial for these lesions is often not interpreted in accord-

ance with the criterion set down at the head of this paragraph, but in terms of an irremovable plaster jacket for weeks, or even months, at a time Not only is their convalescence unduly prolonged but the patient has back muscles weakened by disuse and easily fatigued when the plaster is removed This results in spasm and pain which is treated by physical therapy modalities which temporarily relieve the *symptoms* due to fatigue and spasm When the fatigue and pain and spasm recur on attempts at normal function, *it is felt that more rest is needed* and a new plaster jacket is applied One has only to appreciate the *yearly multitude of* backs which have suffered such lesions and which are under treatment for months on end to realize that rest of the muscular system beyond the demands of the criterion here set down is indeed a two edged sword

2 Procedures or activities which induce fatigue or pain leading to muscle spasm are usually ill advised This is too frequently interpreted in terms of the procedure rather than in terms of its frequency, its intensity, and its duration, whether the matter be one of exercise, of a physical-therapy measure, or of a manipulative procedure Digitalis is a good drug for certain cardiacs, provided the individual dose, the frequency of dosage, and the duration of administration are evaluated in terms of its effect upon the organism A patient will frequently benefit far more by one or two minutes of exercise every hour on the hour than he will by a full half hour night and morning

3 All functional activity should aim at diffuse but smoothly coordinated and "relaxed' muscular contraction rather than at the accomplishment of individual movements This is exemplified by the superior results of purposeful exercise, such as is seen in occupational therapy, as opposed to the use of set exercises such as wrist flexion, wrist extension, pronation and supination performed as individual set exercises It can be accomplished by the use of activity which involves the extremity rather than just the injured structure It can be furthered by the use of bilateral exercise, making the good extremity or part keep pace with the injured one rather than by attempting to make the injured part keep pace with the good one It can be helped by the aid of rhythmicity through counting, metronome timing, or music As an example, light Indian club exercise (using only half pound clubs) to the rhythm of music will accomplish startlingly rapid and effective rehabilitation in a shoulder with muscles stiffened by disuse or injury as *compared with wall crawling broom* handle, nonrhythmic pendulum swinging, or other set exercises of a nonrhythmic nature The rhythmicity of the exercise to a large degree calls into play the element of coordination

4 When set exercises are used, they should be demonstrated to and by the patient The instruction for exercise is often Keep your wrist moving, or, more specifically, 'Exercise your wrist, elbow, and shoulder every hour for two minutes' It is astonishing the number of patients who will carry out these instructions by hunching the shoulder up and down for shoulder exercise, by waving the fixed elbow about by means of abduction, forward elevation, and circumduction at the shoulder for elbow exercise, and by waving the fixed wrist about by movements at the elbow and shoulder for wrist exercise We far too often forget the fact that the effective meaning of language lies in the listener s interpretation, not in the thoughts and intentions of the speaker

5 In the use of physical therapy it is essential that, while recognizing its specific effects and realizing its distinct value when intelligently used, we realize that its major value by far lies in the degree to which it makes active function easier to accomplish, rather than in the feeling of comfort which it induces It

is to be evaluated by the answer to the question "What can you do now?" rather than "How do you feel now?" It is to be regarded either as a desirable adjunct to functional activity or merely as a partial substitute for it, regrettable in the last instance by reason of its necessity.

MUSCLE STRAINS

By this term is meant the overstretching or rupture of some muscle fibers without gross muscle rupture, and with a certain amount of bleeding and some infiltration by inflammatory exudate and effusion associated with local vascular stasis. There is induced a variable amount of pain and tenderness, spasm, swelling, and functional ineffectiveness. Common sites for it are: the psoas, giving groin pain; the thigh adductors; the back muscles, in lifting or torsional effort; the hamstrings, by sudden and severe knee- or hip-bracing efforts; the biceps humeri; the pronator teres; the deltoid; and the neck muscles.

The treatment indicated in the mild cases is rest within the meaning of the term as previously described, plus measures designed to eliminate the infiltrating hemorrhage and exudate and to relieve the local circulatory stasis. In general, rest is secured by strapping, by felt or cotton compression dressing, and by limited use, short of pain and spasm. Concomitantly, physical-therapy measures such as massage, heat in the form of repeated hot wet compresses, low degrees of radiant heat such as infrared or the therapeutic lamp, low degrees of heat from an electric pad, or low milliamperage diathermy are helpful in combination with active but gentle exercise of the part within the limits of pain and spasm for short periods at frequent intervals. Complete rest of the part is to be avoided in these cases. The aim of treatment is rapid restoration of function—not merely symptomatic relief. Analgesics such as aspirin are adequate in these mild cases.

If one or more areas of acute tenderness are present, the injection of a local anesthetic such as novocaine or eucupin may be of distinct aid *if it allows free exercise without pain or spasm.* It is a mistake to use it merely to relieve pain or soreness. If it gives the desired relief, active exercise while that relief is in force will often materially speed up the recovery, and minimize the temporary disability.

In this connection the use of iontophoresis of novocaine in the regions of demonstrable tenderness is said to be effective enough to allow of active use in some cases, and to obviate the necessity for the local injection of the anesthetic. Its use purely for relief of pain is subject to the same comments as made on the use of local anesthetic injection.

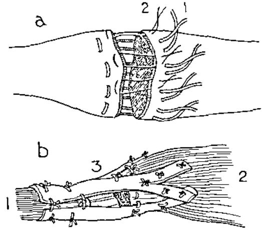
The criterion by which to judge the value of therapeutic measures in these cases is the amount of painless function without spasm which is possible as a result of their use.

In the more severe cases the general handling is identical except that rest may have to be more complete and for a longer time The adjuvant measures should not be neglected, and any function which can be secured without pain or spasm is not only allowable, but is therapeutically indicated.

The specific handling of these lesions in back cases is an important matter in industry (see Chapter 9).

CONTUSION OF MUSCLE

This condition is subject to the same general remarks, and is handled in general in the same fashion as muscle strain of similar intensity. In the severe cases, if seen very soon after injury, packing in ice, or the use of continuous iced dressings, may materially decrease the extent of the pathologic process. This is of no value once the pathologic process has advanced. Ordinarily the use of this procedure is worth while only within the first eight hours, and only in severe cases. It should not be continued beyond the first 12 hours.



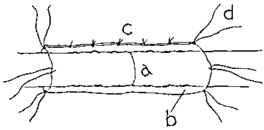


FIG 987 (*Top* and *Center*) Repair of muscle (a) Fresh rupture or laceration Ends trimmed smooth (1) Mattress sutures go through both sheaths if possible (2) Small coaptation sutures for edge of sheath are then placed and tied (b) Old laceration (1) Tendon the end of which has been freshened (2) Retracted muscle belly pulled down as far as possible the end freshened and purse stringed (3) Fascia lata strips fanned out on muscle surface and sutured to aponeurosis Point of split in each strip caught by suture The use of silk throughout is advisable

FIG 988 (*Bottom*) Provision against adhesions *after tendon suture or graft* The sutured tendon (a) is covered by paratenon or fatty tissue (b) sutured with edges everted (c) and caught by its ends to surrounding tissue (d) Sheath extends well beyond area of suture on each side

In two regions particularly severe contusion is apt to be accompanied by the formation of an appreciable hematoma in the muscle although this may of course occur anywhere The rectus femoris muscle and the heavy back muscles because of their size and location are the most notable regions

When a hematoma occurs evidenced by rapid swelling and tension with demonstrable or suggestive fluctuation early aspiration followed by compression dressing and the treatment for contusion may shorten the story and diminish the chance of a subsequent myositis ossificans Late aspiration is usually unsuccessful as the hemorrhage usually infiltrates into the adjacent muscle and fascial planes after relatively few hours

When myositis ossificans develops as the result of muscle contusion or strain all local treatment by massage heat or diathermy should be abstained from Locally concentrated therapy seems to increase the speed certainty and amount of ossification Why certain contusions should ossify and others should not is as yet not explained Certainly no bone or periosteal damage need occur and the bone is formed in the connective tissue replacement in the muscle first and acquires any bony attachment secondarily Empirically normal use within pain and spasm limits abstention from local therapy and from forced active or passive exercise and watchful waiting until the bone formation and regression have passed through a rather definite cycle is the indicated therapy The nature of the cycle and the treatment for the residual ossification is described in Chapter 22 under myositis ossificans as a fracture complication

RUPTURES AND LACERATIONS OF MUSCLE

When rupture of a muscle secondary to either direct or indirect violence occurs it is usually at the musculotendinous junction the tendinous portion pulling out of the muscle It may however be across the muscle belly itself The fascia sheathing the muscle is usually torn and retraction of the muscle ends occurs Occasionally the belly of a muscle may rupture completely across within the intact sheath When this occurs

it is suspicious of a pathologic state in the muscle itself, and degenerative or other changes should be looked for at operation.

These cases should be repaired early—and by early is meant as emergencies. It is a mistake to delay operation until the swelling goes down and until the hematoma is absorbed. Not only does the separation of the muscle ends become progressively more difficult to correct because of contracture, but the infiltration of muscle belly and sheath by hemorrhage and exudate renders both increasingly friable and difficult to suture securely.

It is necessary to approximate the torn ends snugly for satisfactory results. In order to do this, mattress sutures are indicated, and the sheath of the muscle both in front and behind should be included (Fig. 987). Postoperative splinting is indicated for a period of ten days or two weeks in the position which minimizes stretch and tension. For the next two weeks gentle and gradually increasing active exercise with the splint removed is practiced several times daily, the splint being replaced after exercise. At the end of four weeks the splinting can be discarded and active exercise without splinting progressively enforced. Physical therapy is employed as an adjuvant throughout.

When the muscle is ruptured within the intact sheath, the anterior sheath should be opened, the contracted ends of the muscle pulled together, and the mattress sutures should go through both sheaths.

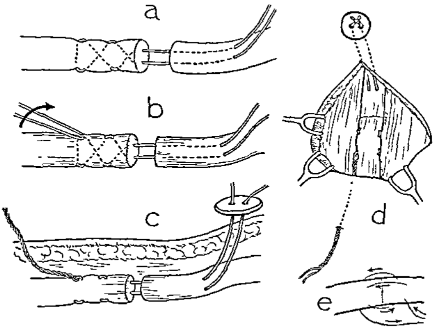


FIG. 989 A. Bunnell method of removable wire tendon suture.
(a) Wire braided through proximal part and passed through distal part of tendon.
(b) Removing wire placed.
(c) Ends of wire through distal segment brought out through a button on skin. Removing wire brought out through small skin incision proximally.
(d) Completed suture. Removal is accomplished by cutting end of wire passing through button and pulling on removing wire.
(e) Additional very fine silk double right-angle suture for edge approximation if necessary.

RUPTURES AND LACERATIONS OF TENDONS

When operation is indicated in these cases it should be done early, preferably as an emergency In suturing tendons, all sutures must be buried, and the site of suture should be protected against adhesions to the surrounding tissue In addition, special types of suture are indicated, since there is a great tendency for sutures to pull out

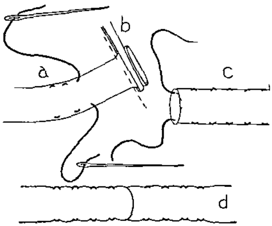


FIG 989 B End to end tendon suture (Bunnell) (a) Method of placing separate sutures in each section, while tendon is held in small Kocher clamp (b) The ends of the suture are brought out through tendon end after the latter is cut smoothly across at the dotted line (c) Completed placing of suture Note point of emergence of suture ends (d) Completed suture The two tendon ends have been accurately approximated, and the tied ends of the suture on each side are buried, ties actually being within substance of tendon tissue

The protection against adhesions may be provided for in several ways The thin film of areolar tissue which lies between fatty subcutaneous tissue and deep fascia or over the triceps or Achilles tendons may be dissected off as a veil like sheet with a sharp scalpel and wrapped around the tendon at the point of suture and for an inch or two on either side of it This is probably the best method The areolar envelope so formed is caught with a few very fine buried sutures Silk is preferred A thin envelope of subcutaneous fatty tissue may be used, but is not so satisfactory Artificial substitutes for these have in general proved unsatisfactory (Fig 988)

In all tendon repair, carefulness of technic and great gentleness in the handling of the tissues is of paramount importance A minimum of tissue reaction is not only desirable, but is essential if adhesions and scar-tissue freezing are to be avoided Minimal and gentle handling of the tissues, careful hemostasis with fine clamps, and the use of the finest possible sutures and ligatures of silk or cotton are necessary features Since even very low grade infection or "wound reaction" may vitiate the results, the operative technic as regards asepsis must be particularly good

METHODS OF TENDON REPAIR

End-to-end This is illustrated in Fig 989 The technic is that of Bunnell Its advantages lie in that the sutures are buried, the chance of the sutures pulling out is practically nil, and the strain is well distributed with a minimum of reaction It is ideal in those regions where the occurrence of adhesions or scarring is of great import

Another method of suture has been recently described by Bunnell, using a stainless steel wire The suture is so inserted that at the end of three weeks it can readily be removed from the tendon without operation, and in the interim it leaves the line of junction of the two cut ends completely free from strain It consists essentially in passing a wire suture through the portion of the tendon attached to the muscle belly by the technic shown in Fig 989, passing the two emerging ends of the suture directly through the distal segment of the tendon for a distance, then to emerge through the skin, where they are passed through and tied snugly over a button A second piece of wire is passed about the proximal looped end of the suture, its two sides twisted

tightly together, and is brought out through the skin some distance proximal to the proximal end of the tendon suture as shown in Fig. 989 A. This second wire is the removal wire. All pull exerted by the muscle belly is taken by the button, thereby relieving the junction of tendon ends from

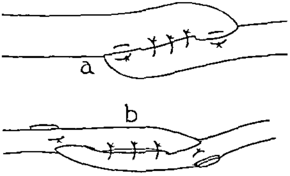
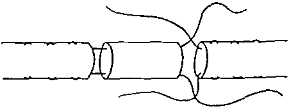


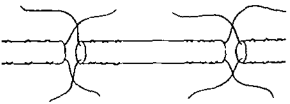
FIG. 990. Side-to-side tendon suture: (a) Without perforation; (b) with perforation.

strain during healing. After healing is accomplished, the button is cut off, and the suture is withdrawn by pulling on the removal wire attached to the proximal end of the suture. This principle can be employed for tendons practically anywhere, including the Achilles tendon, the quadriceps tendon, the patellar tendon, etc. It represents an important advance in finger tendon suture, and is of advantage in the other sites as well.

Side-to-side. When adhesions and scarring are not of such importance, and where early function under considerable strain is desired (as in the forearm or leg) a side-to-side suture with or without perforation may be used to advantage. The author prefers the procedure with perforation (Fig. 990). In these cases the apposed surfaces should be scraped or scarified.

Tendon Grafting. Where tendon is destroyed, or where tendon ends are separated due to irreducible contraction of the muscle belly, tendon grafting may be necessary to fill the defect. This is also true where the point of suture of a severed tendon would have to pass to and fro through a particularly narrow or constricted channel. The ends of the two sections of tendon can be excised and a graft placed between them so that neither suture line between graft and tendon end has to glide through the narrow channel. Grafts may be obtained from the long extensors of the toes, from the peronei, or from the palmaris longus. If necessary a thin flat strip of triceps, quadriceps, or Achilles tendon, or of fascia lata, may be rolled into a tube of the appropriate size,





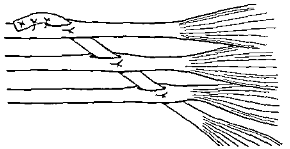
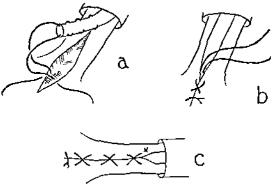


FIG. 991. (*Top*) Method of suture for short tendon graft.
FIG. 992. (*Center*) Method of suture for long tendon graft.
FIG. 993. (*Bottom*) Method of transference to several tendons.

the thin areolar paratenon tissue on the outside, and used as a graft. The method of suturing such grafts depends upon the length of the grafted section (Figs. 991 and 992).

Transplantation of Tendon. When, because of tendon loss or for other reasons, another tendon has to be transplanted to



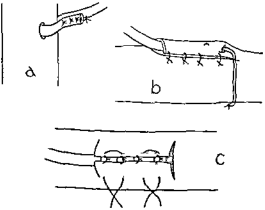


Fig 994 (*Top*) Tendon transplant into tendon insertion (Mayer) (a) Slit in tendon and periosteum at insertion and bone guttered Transplanted tendon passed through sheath of host tendon and suture ends passed through periosteal flaps snugging tendon into prepared gutter (b) Suture tied and continued upward shoestring style to bury transplanted tendon in substance of host (c) Completed suture

Fig 995 (*Bottom*) Methods of tendon insertion into bone (a) Through drill hole with side to-side suture (b) *Under longitudinal osteoperiosteal flap* tendon suture going through drill hole in bone and sutured to opposite periosteum and soft parts (c) Under lateral osteoperiosteal flaps lateral mattresses through tendon coming out through drill holes and flaps sutured down over tendon In all instances surface of tendon to be buried should be roughened

supply power the new tendon may be inserted into the old by the method described in Fig 990 or if more than one tendon has to be substituted for, by the method shown in Fig 993 Insertion of one tendon into the insertion of another for substitution purposes may be carried out by Leo Mayer s method (Fig 994) Fixation of a transferred tendon into bone when there is no residual tendon into which to insert it or reattachment of an avulsed tendon or a substitute for it into bone may be accomplished by one of the methods shown in Fig 995

Tendon Lengthening If tendon lengthening has to be employed it may be done by a Z or sliding tenotomy In a flat tendon this may be done in either the horizontal or the vertical plane (Fig 996) The Hibbs method may also be used if the amount of lengthening desired is considerable (Fig 997)

Tendon Shortening Occasionally tendon shortening may be indicated It may be accomplished by the method shown in Fig 990 or by the Z or sliding tenotomy plus excision of part of the tendon (Fig 998)

In all tendon repairs transferences and re insertions it is to be remembered that it is necessary to have some tension present in order that the tendon may not atrophy On the other hand marked tension which restricts motion range will result in muscle atrophy The tension created should usually allow of full motion range when the procedure is completed without buckling of the tendon during any phase of the movement Too long a graft or too extensive a lengthening is as physiologically unsound as the creation of such tension that marked restriction of motion range results

INDIVIDUAL TENDON AND MUSCLE RUPTURES

Tears of Musculotendinous Cuff in Shoulder These constitute an interesting and important group of cases the significance of which has come to be appreciated in late years by reason of the work of Codman and others Some of the general considerations of this problem have been presented in Chapter 29 A rather changed

concept of the pathologic changes involved and the operative handling of these cases was presented by H. L. McLaughlin in the Journal of Bone and Joint Surgery, 26: 31-51, and its importance is such that the subject will be presented here in some detail by direct quotations and illustrations, as follows:

"The skin incision parallels the strap or suspender line and the normal skin creases of the region; it is situated just lateral to the acromioclavicular joint, and extends from the posterior to a point 3 to 5 cm. in front of the anterior border of the acromion (Fig. 999). That portion anterior to the acromion is deepened, and the underlying deltoid fibers are separated and retracted to expose the roof of the bursa and the coraco-acromial ligament, which are in turn incised and retracted. An exploratory opening (Fig. 1000) is then available through which, by manipulation of the extremity, almost all except the most posterior and inferior portions of the bursa and musculotendinous cuff may be examined, the pathology evaluated, and minor procedures—such as the excision of the bursa or evacuation of calcified deposits—carried out.

At this stage of the approach it should be emphasized that·

1. All deltoid splitting should be near enough to the anterior border of the muscle so that, if terminal axillary nerve fibers are accidentally severed, the amount of resultant atrophy and paralysis will be insignificant, from both a cosmetic and a functional viewpoint.

2. Deltoid splitting should be carried down from, rather than up to, the anterior border of the acromion. In this way no unnecessary splitting is done; danger of involving axillary nerve branches by dissection is minimized; and the circumflex acromial vessels may be identified and controlled at the start, ensuring a dry field.

3. When more complete exposure of the anterior joint region is desired, separation of the deltoid fibers may readily be extended, but each additional centimeter of extension increases the risk of damage to the axillary nerve branches. It is safe to split the proximal

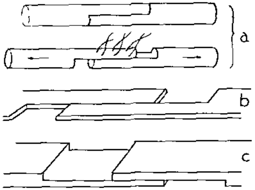


Fig. 996. Tendon lengthening: (a) For round tendon; (b) side-to-side Z—flaps can be sutured side-to-side or placed one on top of the other; (c) anteroposterior Z with sliding of flaps one on the other.

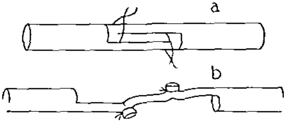


Fig. 997. Hibbs' tendon lengthening: (a) Incisions through tendon and ligatures which are tied before elongation of tendon; (b) tendon elongated.

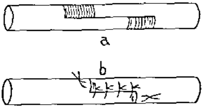


Fig. 998. Tendon shortening: (a) Incisions through tendon—shaded portions are excised; (b) shortened and sutured tendon. In flat tendons, side-to-side and anteroposterior Z tenotomy can be similarly treated.

4 cm of the anterior deltoid and more than this is required only in the exceptional case

When examination through this exploratory opening has indicated the need for a complete exposure of the joint region the skin incision is carried directly backward to the posterior border of the acromion and deepened to bone The acromion is then divided by an osteotome (Fig 1001) When intra articular exploration involving complete exposure of the glenoid is required the osteotomy is directly anteroposterior and about midway between the acromioclavicular joint and the lateral border of the acromion (Fig 999 *Site A*) but for purposes of repair work on the intrinsic muscle cuff a more oblique osteotomy (Fig 999

Through such an opening in the cuff it is found possible to do any of the common shoulder joint procedures with ease A dislocated fragment of the humeral head may be removed from above rather than through the brachial plexu Reattachment of the labrum glenoidale or anterior capsule for recurrent dislocation is carried out from within the joint thus avoiding the trauma caused by transverse section of the coracoid and subscapularis Transplantation of the biceps tendon is done with the added certainty of knowing exactly where the tendon is to emerge from the humeral head since the bony tunnel is made from above downward and the intraarticular point of emergence of the tendon

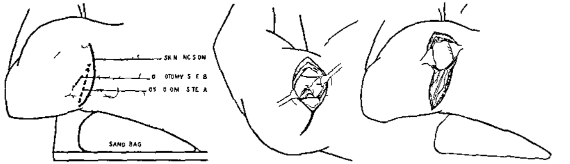


FIG 999 (*Left*) Left shoulder viewed from above showing skin incision and sites for division of acromion process (Courtesy Bone and Joint Surg 26 32)

FIG 1000 (*Center*) View from above left showing exploratory portion of incision (Courtesy Bone and Joint Surg 26 32)

FIG 1001 (*Right*) Left shoulder viewed from above—acromion divided (Courtesy Bone and Joint Surg 26 33)

Site B) deviating laterally to emerge at about the lateral tip of the acromion gives adequate exposure and a little better cosmetic result The loose areolar tissue is next separated from the undersurface of the divided fragment following which the outer flap of the wound is reflected laterally as far as the level of the surgical neck of the humerus making available for inspection the humeral head and the tuberosities covered by the intrinsic muscle cuff (Fig 1002)

A complete survey of the interior of the joint is obtained by making a longitudinal incision through the cuff from the level of the glenoid cavity to the anatomic neck of the humerus This incision parallels the direction of the cuff fibers and may be made through any one of the four tendons but is most useful and least traumatic when located in the aponeurosis joining the subscapularis and supraspinatus tendons

may be placed as far medially as desired Reassemblement and fixation of complicated fractures and fracture dislocations or reconstruction procedures such as that described by Jones are much more simply done since the whole pathologic field is in full view at one time and the soft part tears invariably accompanying such lesions are amenable to easy repair

Multiple sutures of fairly fine silk are used for side to side closure of the longitudinal incision in the cuff and it can be demonstrated by passive manipulation of the extremity at operation that the tension on such a repair is insignificant Consequently the fact that the intrinsic muscle cuff has been opened does not constitute a factor tending to delay mobilization nor has it been observed to delay convalescence to any appreciable extent It should be emphasized however, that such repair must be secure enough

to prevent early mobilization from pumping joint fluid through the suture line to collect in the region of the bursa and exert a deleterious effect on tissue healing.

In closing the wound proper, it is considered advisable to excise and discard the outer fragment of the acromion. The stump is beveled off and reshaped for purposes of obtaining the optimum cosmetic result, and the free deltoid origin is sutured to the rather tough tissue on its superior aspect. If for any reason the fragment is not removed, wound closure is accomplished by soft-tissue suture only; no attempt at bone fixation should be ease with which they are able to commence active mobilization of the extremity, as compared with previous cases in which no division of the acromion was done, or in which division was followed by fixation of the fragments.

Further potential benefits are gained by thus reducing the size of the acromion. If a ruptured cuff has been repaired, such a reduction should mean less surface against which the repair site will impinge on elevation of the arm,—consequently less wear, less postoperative pain, and earlier rehabilitation. If operation for recurrent dislocation has been

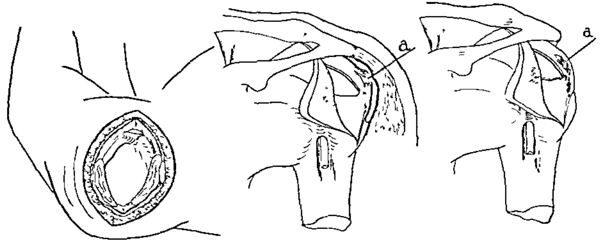


FIG. 1002. (*Left*) View from above of exposure of cuff following division of acromion and retraction. (Courtesy, Bone and Joint Surg , 26:33.)

FIG. 1003. (*Center*) Left shoulder viewed from in front, showing incomplete tear in outer surface of cuff. (a) The tear. (Courtesy, Bone and Joint Surg., 26:35)

FIG. 1004. (*Right*) View from in front, showing appearance of incomplete tear in substance of cuff, surface intact but looking blistered (a). (Courtesy, Bone and Joint Surg., 26:35.)

made. Good union of the bony fragment has occurred in all such cases whether or not fixation was present.

Removal of this fragment has been followed by no functional defects. On the contrary, it has appeared to be of distinct benefit in most cases. Smith-Petersen has pointed out that removal of the lateral portion of the acromion in itself does no harm, and is successful in relieving certain types of shoulder pain. The experience gained in observing the postoperative course of shoulder cases, in which removal has been done in addition to other procedures, has verified his statements. There has been noted not only a distinct decrease in the amount of postoperative pain suffered by these patients, but also a distinct increase in the done, a smaller acromion should mean a less prominent fulcrum over which the humerus may subsequently be levered toward a dislocated position, and a decrease in the potential risk of recurrence. In cases of fracture-dislocation requiring removal of the humeral head, shortening of the acromion and the resultant transplantation of the corresponding deltoid origin to a point more medial than normal should result in a greater mechanical advantage for the deltoid and greater power of abduction. All of these premises now have been adequately confirmed by clinical experience and will be reported in detail at a later date.

The wound, *per se*, requires no particular after-care, and the postoperative management

of the extremity may be dependent upon the condition for which the operation was done Immediate mobilization has not resulted in any tendency for the deltoid to separate from its transplanted position, but it is considered advisable to have the patient refrain from active elevation or abduction against gravity for a period of about two weeks, after which active raising of the arm with support may be commenced

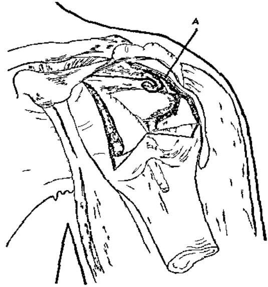
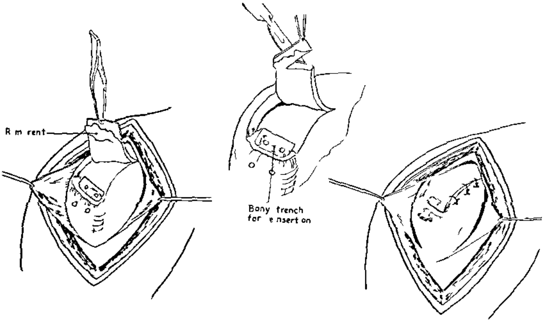


Fig 1005 (*Top*) View from in front, showing incomplete tear involving deep surface of cuff Torn under portion is curled back into joint (A) (Courtesy, Bone and Joint Surg, 26 35) (*Bottom*) Method of repair for incomplete tears



I INCOMPLETE RUPTURE

Such a tear is incomplete in the sense that it does not involve the whole thickness of the cuff It may be situated on the superficial surface of the cuff so that the resultant irregularity in the floor of the bursa produces a constant source of chronic irritation on motion of the joint (Fig 1003) It may be located within the substance of the cuff, so that it involves neither surface (Fig 1004),

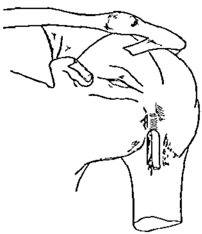
and there is evidence to indicate that the deposition of calcium salts in the tendons constitutes one manifestation of the poor healing qualities of such a lesion. On the other hand, it commonly involves only the deep surface of the cuff, so that the retracted tab of tissue may produce an internal derangement of the shoulder joint in much the same way that a mobile tab of medial meniscus produces symptoms in the knee (Fig. 1005 A).

II. COMPLETE RUPTURE

Such a tear is complete in the sense that it involves the whole thickness of the cuff Wilson, without undue tension on the repair site.

B. *Pure Vertical Rents or Longitudinal Splits Paralleling Direction of Cuff Fibers*

Such a tear is most frequently found in young persons, whose tendinous cuff is thick and strong enough to withstand transverse rupture, and invariably has been situated in the aponeurosis uniting the subscapularis and supraspinatus—that portion of the cuff aptly described by Jones as the coracocapsular ligament. A small split of this type (Fig. 1006)



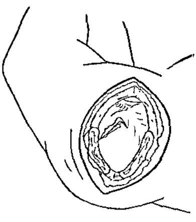


FIG. 1006. (*Left*) Small longitudinal split viewed from in front. (Courtesy, Jour. Bone and Joint Surg., 26:36.)

FIG. 1007. (*Center*) Large longitudinal split viewed from in front. (Courtesy, Jour. Bone and Joint Surg, 26:36.)

FIG. 1008. (*Right*) The beginning of a longitudinal split superimposed on a transverse tear. Left shoulder viewed from above. (Courtesy, Jour. Bone and Joint Surg., 26:37.)

and results in a direct communication between the subdeltoid bursa and the joint cavity. This group of lesions may be divided into four main categories:

A. *Pure Transverse Rupture*

This is an uncommon lesion. It has not been encountered in a young person with a healthy cuff, and is usually to be found in the age group past 35, and in persons whose cuff has become weakened by attrition. Because it is purely transverse, with both ends of the torn portion adherent to the adjoining intact cuff, minimal retraction is the rule; and for this reason such tears are amenable to direct end-to-end suture or reinsertion into the anatomic neck of the humerus as described by

probably heals spontaneously under favorable circumstances, but on occasion has been found to give rise to protracted symptoms requiring late repair. In a longer split, however, the edges are pulled apart by the divergent forces of the subscapularis and the external rotators, and an elliptical hiatus is produced in the anterosuperior part of the cuff (Fig. 1007). The largest such lesion—three by two inches —found to date was in a teen-aged girl, and was accompanied by a gross subluxation of the humeral head which disappeared following side-to-side repair of the ununited rent.

Commonly, the splitting apart of the fibers extends as far laterally as the level of the surgical neck of the humerus, and, as it passes over the greater tuberosity, involves the bone

(in the form of a fracture of the tuberosity) as well as the overlying tendinous envelope Under such circumstances the humeral head loses the support of its posterior and superior stabilizing muscles and aided by the unopposed pull of the intact subscapularis rolls downward and forward into a dislocated position Such dislocations are found to be intracapsular in nature with the anteroinferior joint structures essentially intact

C *The Tear with Retraction*

The general conception of a retracted tear of the cuff has been of a more or less transverse rupture extending across the fibers or scarring and degenerative changes This fact must be taken into consideration and the degenerated scarred peripheral edges of any tear must be excised back to normal vascular tissue before repair may be done with optimum chances for healing

In the second place while immediate operations on fresh injuries have indicated that the primary tear is usually transverse in nature explorations at various later periods following injury have demonstrated that certain changes in the nature of the lesion quickly and inevitably occur The cuff might be likened to a sheet of cellophane which so long as it remains intact has great tensile strength but

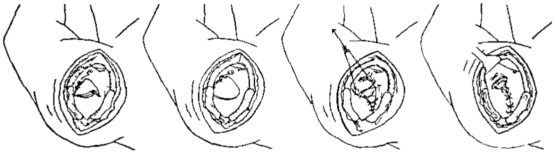


Fig 1009 (*Left*) Commencement of retraction following extension of split Left shoulder viewed from above (Courtesy Jour Bone and Joint Surg 26 37)
Fig 1010 (*Center left*) Eventual form of tear following retraction Left shoulder viewed from above (Courtesy Jour Bone and Joint Surg 26 37)
Fig 1011 (Center right) Showing placement and action of continuous suture after excision of scar tissue edges of tear (Courtesy Jour Bone and Joint Surg 26 38)
Fig 1012 (*Right*) Showing continuous suture pulled taut and tied through lateral aspect of greater tuberosity (Courtesy Jour Bone and Join Surg 26 39)

avulsing the tendon from its bony insertion and the suggested methods of repair have been designed to combat this type of lesion by end to end suture or reinsertion of the retracted fragment into the anatomic neck of the humerus It is probably safe to say that this is a misconception which has been and is the most important single factor in the production of unsatisfactory results because a transverse rupture is seldom found alone and pure end to end repair is frequently contraindicated Before a rational plan of repair can be conceived an understanding of the following characteristics of the mechanics of the rupture is necessary

In the first place such ruptures seldom occur except in tendinous cuffs that have been subjected to sufficient use and attrition to make them thin and weak and the seat of which once a small rip is started progressively tears more and more with each additional strain placed upon it The corresponding lesion taking place in the tendinous cuff consists of a progressive splitting apart of the fibers commencing at one end of the original transverse rupture (usually the anterior end) and extending medially to produce a longitudinal split parallel to the long axis of the fibers (Fig 1008)

Undoubtedly some injuries are such that both the transverse and splitting portions of the tear are produced simultaneously but more important is the fact that once established the extent of both portions may be increased by minor traumata or sudden movements of the extremity At operations on patients whose acute symptoms dated from a recent injury, it has been noted repeatedly

that the cuff pathology consisted of a rupture of obviously long duration upon which was superimposed a recent extension of the preexisting tear.

As the splitting portion of the lesion extends medially, it becomes subject to a new mechanical force. The subscapularis pulls its anterior edge forward, while the external rotators pull its posterior edge backward; and in this manner the typical crescentic or triangular hiatus begins to form (Fig. 1009). Time and cicatrization further camouflage the true nature of the lesion, so that on superficial examination it appears to be nothing more than retraction superimposed on a transverse tear (Fig. 1010). Attempts to repair this type of lesion by end-to-end suture or by reinsertion of what appeared to be the retracted end of a transverse tear into the anatomic neck of the humerus, especially if the gap to be closed was further increased by excision of the scarred avascular periphery of the tear, too often have been unhappy experiences for both the patient and the surgeon.

As a result of the realization that a retracted lesion must be a combination of the transverse and longitudinal tear, a corresponding change in the method of repair has been developed. Actually the change is in principle rather than method, and is characterized by two important departures from the generally used technic of end-to-end repair The first is that the size of the hiatus in the cuff and, *ipso facto*, the amount of retraction, is decreased by side-to-side rather than by end-to-end repair. Codman recognized that such a procedure would be much easier than the end-to-end method, but considered it unwarranted, because it appeared to distort the normal anatomic mechanics of the structures involved. The second is that no attempt is made to restore normal anatomic reposition of the structures involved past the point of tension. Reinsertion of the retracted portion of cuff into the humeral head is done at whatever point it will reach with ease, with the arm at the side, rather than at its normal point of insertion, the anatomic neck. No specific technic can be laid down for the repair of all retracted lesions, since their diversity of shape and size demands different methods; some require mainly a side-to-side repair while in others the main part of the repair will be end-to-end. Some combination of the two is usually indicated.

One prerequisite of any efficient repair is good exposure and adequate working room. The transacromial approach, utilizing the oblique type of osteotomy, has been found superior to any other for this purpose. With the tear completely exposed, its degenerated and scarred edges are excised back to viable tissue The crescentic hiatus is then made into a long V-shaped opening which points medially (Fig. 1011).

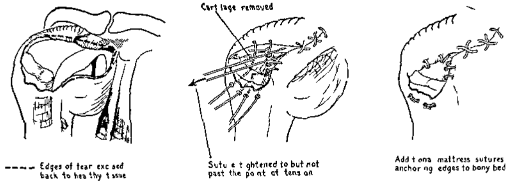
A shoelace type of continuous suture is started at the medial extremity of this opening, and is placed so that traction on its ends pulls the two edges of the opening together side-by-side. This suture is pulled snug up to, but not past, the point of tension. When this has been accomplished, it will be found that only a small V-shaped opening remains. The area of the humeral head visible through this residual opening is next denuded of articular cartilage, so that the edges of the opening come into contact with raw bone, and the two ends of the continuous suture are passed through drill holes and are tied at the outer surface of the greater tuberosity (Fig. 1012). Frequently the residual gap in the cuff is so large that the stabilization produced by the main suture is not sufficient to anchor its edges down securely to the denuded area of the humeral head. When this is the case, additional mattress sutures are required (Fig. 1013).

The net result of such a procedure is that two healthy vascular cuff edges are brought together, and are held with minimal tension by the main continuous suture Inasmuch as the suture is tied on the lateral surface of the bone, any additional tension subsequently placed upon it by movement of the extremity will tend to pull these edges together rather than apart. The remaining lips of the cuff opening are fixed in apposition to raw bone surface in whatever location they will remain without tension, with the arm at the side. At times small ruptures with mild retraction may be excised and fixed directly to the bone underlying the edges of the tear, but such cases seem prone to a more uncomfortable and protracted rehabilitation period than similar cases in which a side-to-side revision has been done. The technic described has the theoretical disadvantage of some small distortion of the mechanics of the joint by failure to secure normal anatomic reposition of the tendons involved. However, the advantages of a snug but tension-free repair—no matter what the shape of the tear or the amount of retraction—of not having to maintain the extremity in an abducted position for fear of disruption, and of early active motion and use

of the arm are practical and important [See also Chapter 41 —Ed]

D *Massive Avulsion of Cuff*

The mildness of the defect resulting from even gross transplantation of the cuff insertion is well illustrated by the results in the eight cases which belong in a class by themselves All were similar to what Bosworth has called the lesions were repaired in a manner similar to that depicted in Fig 1014—by as much side to-side suture as could be managed without tension and by reinsertion of the cuff into the superior surface of the humeral head so that its suspensory function, as described by Jones was maintained The most recent patient who is still in the early postoperative stage and whose result cannot as yet be evalu



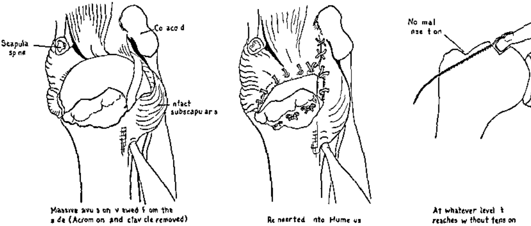


FIG 1013 (*Top*) Excision of avascular scarred edges with side to side revision of large tear with gross retraction
FIG 1014 (*Bottom*) Pathology and repair of massive retracted tear

a massive avulsion of the cuff—that is a complete avulsion of the external rotators with retraction almost to the level of the glenoid made possible by a longitudinal split completely separating the supraspinatus from the subscapularis (Fig 1014), and at times involving the tendon of the latter as well At times the retracted cuff becomes interposed between the glenoid and the humerus Symptoms of pressure on the brachial plexus, resulting from the almost invariable chronic subluxation of the humerus, are common All ated, had a Nicola transplantation of the long head of the biceps done in addition to the cuff repair It is possible that this should be done in all such cases but none of the other seven patients has shown any tendency toward subluxation of the humeral head when the lesion was repaired by reinsertion of the cuff alone Therefore, it is considered that the addition of a Nicola procedure does not give more than a little extra assurance of stability of the humeral head and is not required except in the occasional case where the re-

inserted cuff appears to give inadequate stability and suspension as a result of its grossly transplanted insertion.

There has been no set regimen for postoperative care. Physical therapy is useful when it is employed to help the patient progress in a program of active exercises, but is considered to do much more harm than good when the patient gets the idea that the treatments are doing something active toward his rehabilitation. Under the latter circumstance, progress is almost always in reverse. Maintenance of mobility and gradual progressive resumption of use is the essence of the aftercare, but only one person, the operating surgeon, whose judgment is tempered by a knowledge of the size of the lesion, the condition of the tissues involved, and the security of the repair, is qualified to evaluate the speed and completeness with which motion and use may be allowed. Immediate gentle motion in balanced suspension is the rule until the wound is healed. The patient is then allowed out of bed and is taught a program of active, gravity-free, pendulum exercises. As soon as symptoms and strength permit, wall-crawling and gibbet types of exercises are added. All exercises should be in short periods at frequent intervals, and should be done up to but not past the point of pain or fatigue. Five-minute exercise periods every hour on the hour are considered ideal. All patients are encouraged in the immediate resumption of normal light function, but as a rule active elevation of the extremity is not allowed until some time between the third and seventh week, depending upon conditions observed at the time of operation.

Fine stainless-steel wire was used for the main repair suture in two cases. Symptoms of bursal irritation developed in both more than a year after operation, and the resulting chronic bursitis did not subside in either case until after the metal sutures were removed. No. 3 Deknatel or No. 5 Pearsall silk was used in the remaining cases, and has been found to be very satisfactory for the purpose."

Operation for Repair of Rupture of Long Head of Biceps Brachii. This is described in Chapter 29.

Repair for Avulsion of Tendon of Insertion from Muscle Belly or from Biceps Tubercle of Radius. This may be necessary. When avulsion of the tendon from the muscle belly is seen early, the repair is effected as in Fig. 987 A. When encountered late, retraction of the muscle may make it impossible to secure adequate apposition for safe suture after all scar tissue is excised. Repair will then involve the use of fascia lata strips, as in Fig. 987 B. When the insertion of the tendon is avulsed from the bicipital tubercle of the radius, reattachment to the radius is technically difficult, and when attached to the anterior surface the supinator power of the biceps is lost. It is preferable to suture the avulsed tendon to the deep tissues over the upper ulna—the insertion of the brachialis anticus and the fascia over it. The brachial vessels and the median nerve are kept to the outer side of the point of suture, so that they lie on the brachialis anticus and the biceps tendon passes over them to its point of suture.

Immobilization in flexion at right angles by a posterior molded splint, with gentle active flexion from this point toward full flexion started at ten days, and removal of the splint and beginning extension in a sling at the end of three weeks constitute the postoperative régime.

Rupture of Extensor Longus Pollicis. This occurs at times as the result of injuries to the wrist, particularly in Colles' fracture, or at times spontaneously, presumably as the result of constant occupational strain. When it occurs in Colles' fracture and other wrist injuries it is usually a late development several weeks after injury and occurs in the groove on the radius. The loss of ability to extend the thumb appearing in the course of convalescence may occur six weeks or more after the injury. Since the rupture in these cases is the result of preceding degenerative change, the tendon ends may be frayed and friable. If end-to-end suture of the freshened ends (Fig. 989) is possible it may be done.

Postoperative immobilization in extension for two weeks, with extension exercise of the muscle in that position, may be fol-

lowed by gradual resumption of regular function

The proximal end of the tendon may retract considerably, and the incision to find it may therefore have to extend upward for some distance

When end to-end repair is impossible or entails undue tension a free graft of tendon and paratenon may be employed between the freshened ends of the rupture (Figs 988 and 992) In this case a long enough graft should be used so that the suture lines joining graft to tendon do not have to play through the groove

In long standing cases where there has been considerable retraction of the prox imal end in those cases in which con siderable roughening and irregularity of the

Fig 1015

Fig 1016

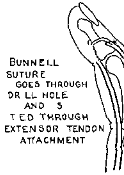


Fig 1017

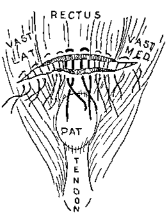
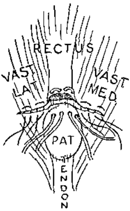


Fig 1018



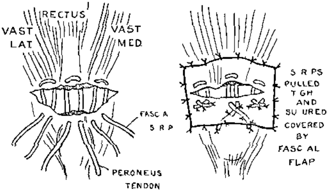


Fig 1019

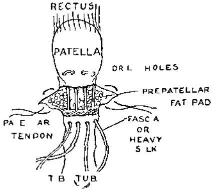


Fig 1020

Fig 1015 Repair of avulsion of extensor tendon insertion into terminal phalanx of finger Note hyperextension of terminal interphalangeal and flexion of middle inter phalangeal joints—the position for postoperative immobilization

Fig 1016 Repair of finger flexor tendon avulsion Suture goes through drill holes and is tied through extensor tendon insertion

Fig 1017 Repair of suprapatellar rupture of quadriceps tendon Mattress sutures include both surfaces of tendon

Fig 1018 Repair of quadriceps tendon avulsed from patellar margin Fascial strip or heavy silk can be used

Fig 1019 Repair of old quadriceps tendon tear with retraction of muscle

Fig 1020 Repair of recent patellar tendon tear

groove exist, and frequently in those cases in which simple end-to-end suture presents any difficulties, it is simpler and more effective to join the distal end of the tendon to the adjacent radial extensors by the technic shown in Fig. 990, with the thumb and wrist in extension.

When suture or graft is done, the sheath should be closed after the tendon is replaced in the groove, if possible, or the groove roofed over by a reflected flap of adjacent periosteum or fascia.

Avulsion of Extensor Tendon from Its Insertion into Distal Phalanx of Finger (So-called Drop Finger or Mallet Finger). This is not very amenable to operative treatment in the late cases. If it is attempted, it should be done as a primary procedure, certainly within the first two or three weeks. It is not advisable as a sequel to unsuccessful conservative treatment at the end of eight or more weeks. [See Chapter 34 for conservative treatment.] The approach is through an L incision, the transverse arm through the dorsal crease and the longitudinal arm distally along the side of the phalanx. The proximal end of the avulsed tendon, with its attached bone fragment if it has been avulsed, is drawn down to contact the base of the extended terminal phalanx, and, after roughening the surfaces to be apposed, is fastened by silk sutures passing through drill holes in the phalangeal cortex on either side just distal to the joint. The skin is closed, and the finger immobilized for four weeks in hyperextension of the distal phalanx and moderate flexion of the middle interphalangeal joint (Fig. 1015).

In the early cases when an avulsed bone fragment is present, this offers good chance of success. When avulsion of the tendon without an attached bony fragment has occurred, it will more often than not be found impossible to get the frayed avulsed end to the desired point of attachment. The attempt to use fascial transplant or fascial sutures is quite unsatisfactory. The operation is therefore advisable only in early cases as a primary procedure when a fragment of bone has been avulsed with the tendon.

Avulsion of Flexor Insertion into Distal Phalanx of a Finger. This is occasionally seen. The problem here is different from that of the extensor insertion. Good soft-part covering is present, and the insertion is much less attenuated than in the case of extensor tendon. These should be repaired. The technic employing a Bunnell suture is demonstrated in Fig. 1016.

Rupture of Quadriceps Femoris. If this is through the body of the muscle, within or including the sheath, the repair is done as described for rupture of a muscle belly earlier in this chapter. Such tears are rare. The usual tear is through the suprapatellar portion of the tendon and its lateral expansions, and occasionally an avulsion from the patellar margin is encountered. In the former instance, repair is accomplished as illustrated in Fig. 1017. When avulsion from the patella is encountered, fascia lata strips through drill holes in the patella are advisable (Fig. 1018). When the tear is old, and retraction of the muscle belly with scar intervening between it and the tendon stump is present, a repair utilizing peroneus longus tendon or fascial strips is employed after excision of the scar down to sound tendon ends. If retraction is marked, and attempted apposition of the ends fails to eliminate a considerable gap, an additional sheet of fascia lata may be added, with the external face of the fascia to the outer side (Fig. 1019).

Rupture of Patellar Tendon. This usually occurs by avulsion from the lower border of the patella, but may be the result of avulsion of the tibial tubercle or its epiphysis. The milder degrees of incomplete avulsion of the epiphysis constitute the more severe grades of Osgood-Schlatter's disease (see Chapter 18). Complete avulsions of the tibial tubercle or its epiphysis require operative replacement and fixation

by a bone peg or a stainless-steel wire suture

Fresh cases of avulsion of tendon from the inferior margin of the patella are best repaired by fascial strips through drill holes in the patella (Fig 1020)

In old cases with upward retraction of the patella skeletal traction by Kirschner wire through the patella in order to stretch the muscle is indicated as a preliminary measure The wire is passed from side to

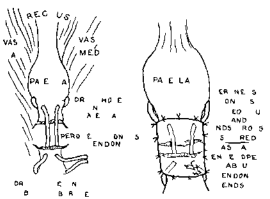


Fig 1021 Repair of old patellar tendon tear with upward retraction of patella

side through the patella in its upper portion as far anteriorly as possible in order to minimize the risk of entering the knee joint Four to eight pounds traction is applied for one or more weeks until the patella is pulled down as far as is possible Repair is then done through an anteromedian incision An inch wide strip of fascia lata or a piece of peroneus longus tendon is utilized After scar tissue has been excised and the end of the patellar ligament freshened the strip of fascia lata is passed through a transverse drill hole in the lower pole of the patella the two ends are braided through the edges of the patellar ligament carried through a transverse drill hole in the tibial tubercle below and the ends sutured to the adjacent edges of the fascial strip The freshened lower edge of the patellar tendon is fastened by additional sutures to the tissue remaining attached to the tibial tubercle (Fig 1021) If traction is not possible or is ineffective the same procedure is used pulling the patella down as far as possible with the addition of a sheet of fascia lata as described above for old ruptures of the quadriceps tendon

The postoperative régime in both quadriceps and patellar tendon repairs is the application of a posterior molded splint with the knee in extension for from three to four weeks with voluntary contraction exercise of the quadriceps in the splint instituted as soon as wound healing is assured At the end of that time the splint can be removed several times daily for circumspect active extension and flexion exercise The exercises are at first best carried out with the patient lying on the abdomen to elicit gravity aid in extension later with the patient on the side to eliminate gravity and ultimately with the patient supine extension then being against the force of gravity From the fourth week on walking with the posterior molded splint or with a knee brace may be practiced with crutches for the first two weeks or so and then with a cane or no support Brace or splint support can be discarded at 8 or 12 weeks and full function should be allowed in from six to nine months depending upon the severity of the tear and the adequacy of the repair

Rupture of Gastrocnemius and Soleus Muscles Partial rupture of these muscles in the calf is what is commonly called rupture or avulsion of the plantaris tendon On sudden exertion as in tennis squash running or baseball a sudden sharp impact is felt in the calf as though from a blow from a ball or a bullet This is followed by severe pain swelling tenderness and ecchymosis and disability in walking or knee and foot extension The idea that the plantaris tendon is avulsed in these cases is erroneous

The condition is very rarely severe enough to require surgical repair of the rupture in the gastrocnemius or soleus If ever indicated the technic is that described

in Fig. 987. Conservative treatment consists of icepacks or iced applications if seen immediately, followed by strapping and pressure dressing. If seen late, heat and strapping and pressure dressing are indicated. In addition, the heel of the shoe on the affected side should be raised so as to keep the foot in plantar flexion in weightbearing, with or without strapping to limit dorsiflexion at the ankle. Later, physical therapy and the raised heel suffice, until normal function is possible. A few weeks usually sees a return to normal function.

In the more severe cases it may be necessary to wear a posterior molded splint with the ankle in plantar flexion and the knee slightly flexed for from a few days to a week, in conjunction with physical therapy and intermittent exercise of ankle and knee within pain limits.

Rupture of Tendo Achillis. This may occur through sudden sharp violence, or it may be seemingly spontaneous in the course of degenerative changes in the tendon (see Chapter 10). In the former case it may be transverse, in which it may be repaired by the technic described for rupture of the quadriceps tendon. Sometimes, however, the ends are badly frayed into strips. In these cases heavy silk or a fascial suture is used. It is woven through the lower fragment, wound about the frayed tendon ends, and then woven into the intact tendon above, and tied after approximately normal length has been restored.

In old ruptures, in which separation of the tendon ends has occurred, the gap fills in with scar tissue. This leaves essentially a lengthened tendon, with a tendency to calcaneus and some calf weakness and limp. The procedure indicated is tendon shortening to normal length. This is best accomplished by the Z tenotomy method shown in Fig. 996. This can be done either by an anteroposterior or a side-to-side Z. Enough of each arm of the Z is removed to restore normal length and tension.

In these operative repairs of the tendo achillis the approach is by an incision five or six inches long, placed just laterally to the tendon, and not directly over it.

The postoperative treatment in these cases consists of a posterior molded splint or circular plaster to the knee with the foot in moderate equinus for three weeks, followed by ambulation in a check brace which prevents dorsiflexion at the ankle for the next four to six weeks.

In those cases where apparent spontaneous rupture occurs due to preceding degenerative change, it is necessary at operation to excise the degenerated tendon. This may leave an amount inadequate for repair. It then becomes necessary to utilize fascia lata or fascia lata and peroneus tendon combined as in repairs of old and neglected ruptures of the quadriceps and patellar tendons.

Occasionally a rupture of this tendon occurs in children. Immobilization in moderate flexion of the knee and in fairly marked plantar flexion of the foot for from four to six weeks will usually result satisfactorily. Dorsiflexion at the ankle should be restricted for another six to eight weeks by a check brace if the child is exceedingly active, or by a raised heel on the shoe of the affected side.

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SECTION THIRTEEN

BIRTH INJURIES OF MOTOR-SKELETAL SYSTEM

43

Skeletal Birth Injuries

EDWARD D TRUESDELL, M D

It would seem scarcely necessary to emphasize the importance of the routine physical examination of the newborn child Yet circumstances seem to favor either the primary omission of this important duty or its postponement and eventual omission The labor successfully terminated and such details as require immediate attention properly attended to, the medical attendant not unnaturally avails himself of the first possible opportunity for some much needed relaxation It is indeed regrettable that the mother, as a result of her keen scrutiny of her newborn child, has not infrequently been the first to detect and report the presence of some abnormality

The specter of congenital deformity haunts the obstetrician on all occasions Trauma to the child, inseparable from prolonged labors and operative deliveries, almost inevitably results in some degree of birth injury to bones or soft parts that demands investigation and appraisal

The presence of a brachial plexus birth injury, particularly in its lesser degree, may not be discovered until several days after birth while a fracture of the shaft of a long bone, or a dislocation of a cartilaginous epiphysis, will at times give surprisingly little evidence of its existence and so escape detection and suitable treatment unless particularly sought for

Familiarity with the common consequences of birth trauma will assist materially in determining the presence or absence of the more important forms of birth injury Skeletal injuries involve almost exclusively the skull and the long bones of the upper and lower extremities Of first importance in the physical examination of the newborn child is a systematic investigation of the skull, clavicles, humeri, and femora for possible fractures, and the humeri and femora for displacement of one or more of their terminal epiphyses

With regard to the long bones it is helpful to know that fractures of these bones, when they occur, are quite uniformly limited to the region of the center of the shaft and that fracture of the neck of the humerus or femur or supracondylar fractures of these bones are very rare as birth injuries The bones of the forearm and lower leg seem to be immune to fracture as a birth injury, while the traumatic dislocation of a normal joint sometimes very closely simulated by the displacement of a cartilaginous epiphysis, has still to be conclusively demonstrated as occurring in the newborn

INTRA UTERINE FRACTURES

The possible occurrence of fractures of the long bones of the child within the uterus in the latter months of pregnancy seems always to have appealed to the imagination of the medical profession Were it otherwise much of the evidence presented in support of such a supposition would re

ceive less ready acceptance. Reports of such injuries appearing from time to time are often based upon doubtful or unconvincing evidence and do not adhere too closely to what is generally accepted as reality.

It is difficult to imagine how sufficient violence could be brought to bear upon a normal long bone of a child within the uterus to cause the fracture of that bone without at the same time rupturing the membranes, rupturing the uterus, and causing the death of the mother from shock and hemorrhage. Convincing evidence of the existence of intra-uterine fractures should be available either before or after the birth of the child before the diagnosis can be accepted. An x-ray examination of the mother's abdomen following an injury adjudged sufficient to produce a fracture of a long bone in an unborn child might readily reveal the fracture directly, or it might evidence itself as deformity resulting from such a fracture, or, if a sufficient interval had elapsed, by the presence of a callous mass such as would normally surround the point of fracture

After the birth of the child a visible deformity affecting an extremity might be discovered, due either to the angulation of bone fragments or to the presence of a callous mass, or both, and similar in all respects to the deformity that might result from a recent birth fracture. If the x-ray examination then reveals the presence of a fracture of a long bone, and if, furthermore, a callous mass is demonstrated as present, then the fracture might be accepted as a true intra-uterine fracture in the usual meaning of the term, particularly so in the case of a normal and spontaneous delivery unassociated with such operative procedures as are the usual cause of birth fractures.

Some degree of familiarity with a few of the common manifestations of conditions likely to present the basis for a mistaken diagnosis of intra-uterine fracture, particularly with the x-ray manifestations of these, will assist materially in preventing the hasty arrival at unwarranted conclusions. Some congenital deformities, chiefly of the deficiency variety, or amniotic bands or adhesions may, at times, be the true explanation of abnormalities present in the extremities of the newborn although they are seemingly best explained by a preceding intra-uterine fracture.

Again, dysosteogenesis in its various forms, as achondroplasia, may seriously affect bone development in general and extensively distort all the long bones, as well as greatly impair their consistency. In these cases the irregularities of bone production are often so extreme as to cause difficulty in distinguishing between what might be accepted as abnormal bone production or the development of a callous mass Here the trophic disturbance is the condition of primary importance, the presence or absence of one or more pathologic fractures being decidedly secondary, whether intra-uterine or not Excluding pathologic fractures secondary to diseases affecting the entire skeletal system of the child, and fractures due to extreme violence resulting in the destruction of both mother and child, intra-uterine fractures affecting normal long bones and due to direct violence received through the abdominal wall of the mother and without very considerable additional injury to either mother or child must be exceedingly rare, if indeed they ever occur. [See Chapter 3 for congenital deformities of the lower extremity which might simulate fracture.—Ed.]

THE SKULL

In view of the liability to head injury to which the child is commonly exposed during labor and delivery and of the frequency and occasional severity of these injuries, it would seem that Nature might have made a wiser selection if the breech rather than the vertex had been ordained as the usual presenting part in the mechanism of labor.

The problem of determining with some degree of accuracy the extent and variety

of birth injury sustained by the badly battered head of the newborn child is not a particularly uncommon one Frequently the presence of excessive degrees of edema of the scalp or of the various varieties of hematomata most successfully conceal the condition of the calvarium beneath As a result of prolonged labor or operative delivery the vault of the skull may undergo an astonishing degree of molding without the production of an actual fracture (Fig 1022) Familiarity with the consequences of difficult labor upon the head of the child will beget both respect and admiration for the ability of the skull and soft parts covering it to absorb the trauma incidental to birth and support the opinion that even apparently alarming damage to these structures does not of necessity imply serious or irreparable damage to the brain beneath Certainly as experience broadens, a policy of conservatism with regard to birth head injuries becomes increasingly tenable

The great majority of birth fractures involving the bones of the vault of the skull will be found to conform to one of two distinctly dissimilar types being either of the (1) indentation or of (2) the fissure variety The former is a trivial injury the latter is too often of serious import involving extensive injury to both bone and soft parts

The indentation type of fracture (Figs 1023 1024) resembles remarkably a dent in a derby hat or the indentation often seen in a pingpong ball It might well be termed a pingpong ball fracture of the skull both because of the appearance of the fracture itself and because the consistency of the bone in which it occurs resembles thin celluloid Practically limited to the parietal bone it is presumably due to the impact of this bone upon the promontory of the sacrum It may occur in normal deliveries and may resemble a so-called greenstick type of fracture more closely than do most fractures to which this term is commonly applied, in that the portion of the bone in

Fig 1022 (*Top*) Intrapartum molding of head In the more prolonged and violent labors the fetal head is frequently excessively molded as shown in this x ray of a newborn child Such distortion of skull may cause considerable injury to meninges and brain without actual fracture of bone While lesser degrees of intracranial hemorrhage and edema of brain or even injury to brain tissue itself may result in such cases it is usual that apparently complete and spontaneous recovery takes place under the usual simple palliative therapeutic measures

Fig 1023 (*Bottom*) Birth indentation of vault of skull Usually involving parietal bone and not necessarily associated with difficult operative deliveries it is rarely associated with evidence of injury to structures within skull

volved is partly bent and partly broken to permit the circumscribed inward displacement peculiar to this particular type of fracture.

Such a fracture can occur only when a circumscribed area of convex surface of thin bone is transformed into a convexity in the opposite direction under the influence of direct pressure.

It is characteristic of this injury that it is a purely local affair, present in an otherwise perfectly normal-appearing and -acting infant, there being no suggestion of injury to the structures within the skull. The prognosis is therefore excellent. In the absence of any contraindication, which is usually the case, the depression should be elevated. A small incision through the skin and periosteum is made across the injured area. A small hole is then bored in the bone near the bottom of the depression, and the bone elevated by means of a hook or periosteal elevator. The parietal bone is exceedingly thin in the newborn child, suggesting a thick parchment, and is readily and quickly drilled through. This done, the elevation of the indentation is easily accomplished.

Birth fractures of the skull of the fissure variety (Fig. 1025) may occur in any one or more of the four large bones composing the vault of the skull, and are almost invariably the product of difficult forceps deliveries. The consequences to the child will be found to vary greatly. There may be but a single fissure with little involvement of the soft parts and little damage to the structures within the skull. In the more serious cases a cranial bone may be extensively crushed, the fracture resembling the comminuted variety, with depression of the fragments and encroachment upon the intracranial contents. Such fractures are quite regularly associated with extensive injury to the soft parts both within and without the skull, the direct result of the trauma plus the accompanying and extensive hemorrhage. Even more than in similar cases in adults a policy of conservatism is advisable in the treatment of these birth injuries. In the less serious varieties the remarkable recuperative abilities of the child can be counted upon to accomplish much more toward recovery than would seem possible

In the more serious cases the shock associated with the injury, deepened by more or less associated hemorrhage, is usually sufficient to preclude the serious consideration of even the more conservative surgical measures. The more formidable attempts to deal with the fragmented bone or with an extensive epidural or subdural hemorrhage inevitably result in further shock to the patient and in additional bleeding, often difficult to control, with disastrous consequences. Watchful waiting and symptomatic treatment are indicated.

THE SPINE

It is not always remembered that the spinal column of the child may share in the birth injuries incidental to difficult or operative delivery. The lumbar spine is very rarely injured, apparently being structurally competent to support such stresses and strains as operative obstetrics may bring to bear upon it. [It is claimed by some that the pedicle defects resulting in spondylolisthesis are the result of ununited birth fractures in the involved lumbar vertebrae (Hitchcock).—Ed.]

The cervical spine, however, is not only more susceptible to injury but is frequently exposed to very considerable violence. When real difficulty is experienced in the delivery of the after-coming head, vigorous traction is of necessity applied to the shoulders of the child, with corresponding longitudinal tension upon the cervical spine, particularly upon its ligamentous structures. There is often combined with this a considerable degree of excessive extension of the child's neck as a part of the manipulation necessary to effect delivery.

Under such conditions a rupture of one or more of the ligaments uniting the cervical vertebrae is the injury most frequently

FIG 1024 Birth indentation of vault of skull x ray appearance is that of a circumscribed depressed fracture Extent to which this depression may take place is shown in this x ray and suggests possibility that damage to inner table of bone involved may be more extensive than external appearance of injury would seem to imply This possibility adds support to opinion favoring elevation of these fractures as promptly as possible following their occurrence a simple procedure even in absence of all symptoms that might be expected to be associated with them

FIG 1025 Fissure fractures of bones of vault of skull in newborn particularly in their more extensive varieties are frequently associated with extensive epidural and subdural hemorrhages Such hemorrhages may be cause of extensive pressure upon cerebral hemispheres and evidences of cerebral injury commonly associated with birth fractures of skull of this type

FIG 1026 Birth fracture of clavicle rarely fails of demonstration in x ray when present in newborn child There is always a complete fracture of the bone near its center with dislocation of the fragments X ray findings vary but little from case to case

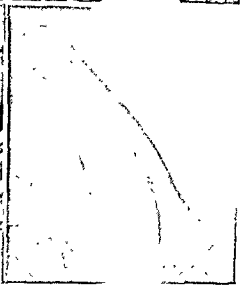

FIG. 1027 (*Top, left*) Birth fracture of shaft of humerus Displacement of fragments is frequent in these cases, usually in form of external angular deformity Since diagnosis of this birth injury presents no difficulty when looked for, and it can be assumed that location of fracture is near center of shaft of bone, it is sometimes convenient to defer x-ray examination until tenth day, as in this case At this time callus surrounds point of fracture, favoring correction of a deformity when present just prior to fixation of fragments by reparative process A swathe dressing can then be applied, deformity being unlikely to recur when thus corrected, and arm fixed to side of chest wall until union is firm

FIG 1028 (*Top, right*) Birth fracture of shaft of humerus, a simple and efficient method of treatment of which consists in a swathe of adhesive plaster passing about chest and holding injured arm snugly against lateral chest wall, providing a satisfactory if imperfect alignment of fragments, with sufficient immobilization A small gauze pad is placed in axilla of injured side Other arm and forearm of injured member are excluded from swathe, it being preferable not to confine hand, particularly fingers, within dressing Dressing is completed by means of a Velpeau bandage supporting affected extremity and shoulder girdle, this in turn being reinforced with narrow encircling strips of adhesive plaster.

FIG. 1029. (*Bottom, left*) Birth fracture of shaft of humerus. X-ray taken through adhesive

satisfactory as they are unnecessary

The aid of the x ray in the diagnosis or treatment of birth fractures of the long bones may be said to vary in importance with the individual bone affected In the case of the clavicle it is unnecessary except at times to confirm the diagnosis, in the case of the humerus it is of interest and instructive, and in the case of the femur it is highly desirable whenever available

The x ray, when employed in the treatment of birth fracture of the humerus, can best be brought in on the eighth or tenth day At this time the position of the fragments (Fig 1029) and the state of development of the callus can be observed to the greatest advantage If there is no angulation of the fragments, the dressing can be renewed for another week or ten days If an objectionable angular deformity is present this can then be readily corrected, as the callous mass is still plastic, and the dressing then renewed The fracture can then be x rayed once more through the dressing to see that satisfactory alignment has been secured and maintained If so, union of the fragments can be expected to take place in the position noted, since the callous mass surrounding the fracture acts as a splint to prevent the recurrence of a deformity corrected, and firm union can be counted upon to take place in a day or two, before the dressing has lost any of its efficiency

If it should happen that firm union has occurred with an excessive external angular deformity, it is entirely unnecessary to refracture and reset the humerus on this account A follow up of such malunited fractures of the humerus in the newborn has shown that these residual angular deformities can be uniformly counted upon to correct themselves During the first few months such angular deformities are transformed into outward curvatures of the shaft of the bone (Fig 1030), and these, in turn, are eliminated within the first two years, the injured bone becoming indistinguishable from its uninjured fellow of the opposite side The time required to bring this about varies with the degree of the deformity

When the fracture of the humerus has been complicated by a brachial birth palsy of the same arm, the elimination of the residual deformity is retarded and may remain incomplete in the more severe cases of paralysis When the outward curvature of the bone tends to persist, indicating trophic disturbances in the bone, refracture of the bone may take place upon slight provocation

THE FEMUR

While the least frequently fractured of the three long bones that may suffer birth fracture, the femur is at the same time, the most important as well as the largest (Fig 1031) The manipulation of the legs necessary in the more difficult breech ex

plaster swathe dressing either at time of its initial application to a fresh fracture or at a later period following correction of a deformity by manipulation of arm usually shows fairly satisfactory position of fragments Since use of splints of one kind or another is difficult and unsatisfactory in fractures of humerus in newborn and as growing bone displays such remarkable ability to eliminate even gross uncorrected deformities during first two years of life simplicity of swathe method of treatment recommends its employment as adequate in these cases, even though it fails to furnish an end to end reduction of fracture when fragments have been dislocated, as is usual

Fig 1030 (*Bottom, right*) Birth fracture of shaft of humerus When fragments have united in a position of external angulation following birth fracture of humerus consequent angular deformity soon becomes transformed into an outward curvature of shaft of bone This curvature may sometimes be extreme during first year of life, but is gradually eliminated during second year, rarely being in any way evident beyond this time in the uncomplicated fracture It will be noted that as time goes on curvature gradually assumes a position relatively lower down shaft of bone due to preponderance of growth at upper epiphyseal line

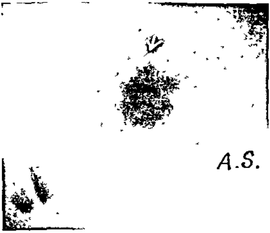

FIG. 1031. Birth fracture of shaft of femur. Due to pull of strong flexor muscles attached to upper fragment, these fractures are almost invariably associated with complete separation of fragments, and an extreme degree of deformity, usually of the anterior angular variety Unless suitable provision is made for this predominant deformity malunion will result with fragments of bone in a most unsatisfactory relationship to each other.

tractions will inevitably result in an occasional fracture of the shaft of this bone Again, in hooking up a leg as a first step in the extraction of the child from the uterus through the incision in its thick muscular wall in the course of a cesarean section, the strain upon the femur sometimes becomes more than this bone can withstand, and a fracture occurs.

The site of the fracture, as in the clavicle and humerus, is quite regularly in the region of the center of the shaft of the bone. As a result of the conditions under which this fracture is ordinarily produced, and because of the pull of the strong flexor muscles attached to the upper fragment, marked displacement of the fragments is usual, the most common being an extreme anterior angulation The fracture rarely escapes prompt detection and treatment is usually begun early. This, obviously, should endeavor to fulfill all the more essential requirements. Not only must whatever deformity present be adequately dealt with, but the usual care of the bladder and bowel must be facilitated, and convenient transportation of the patient and apparatus to the mother for scheduled nursings must be provided for.

It is readily apparent that the treatment of birth fracture of the femur with the leg in extension is highly impractical, since all attempts to overcome the acute flexion of

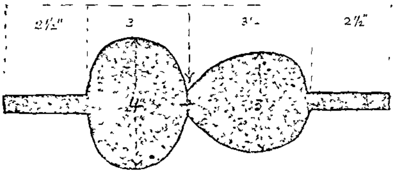

FIG. 1032 Birth fracture of shaft of femur Pattern for construction of van Arsdale splint for its treatment Cut from sheet tin or sheet aluminum, it has been said to resemble two aces of spades placed point to point. The splint is preferably somewhat modified from this general description, the part of splint applied to infant's trunk preferably being somewhat wider than that applied to thigh, while the part applied to thigh should be slightly longer than that applied to trunk.

the thighs upon the abdomen natural in the newborn are persistently and vigorously resisted and will result in producing or greatly increasing an angular deformity Furthermore when the straightened leg is apposed to the front of the trunk with the foot above the corresponding shoulder as in a frank breech presentation the usual anterior angular deformity is transformed into an equally excessive posterior angulation readily demonstrated in the x ray by a lateral view For these reasons a method of treatment that immobilizes the injured thigh in midposition that is at right angles to the body and by so doing avoids the extremes of flexion and extension is clearly indicated

This plan of treatment can best be accomplished by the use of the van Arsdale splint (Figs 1032 1036) Cut from a piece of sheet tin or sheet aluminum with a pair of tin snips and fitted carefully to each individual patient this splint can be counted upon to eliminate all angular deformities and to permit essential cleanliness and such transportation of the infant as may be necessary

In the treatment of birth fracture of the femur the primary and fundamental requirement is the correction of the almost invariable anterior angular displacement of the fragments of the fractured bone These fragments should be placed in a position parallel with each other however much they may be separated It is very doubtful if end-to-end apposition of the fragments once they have been displaced can ever be obtained or, if obtained, retained nor need this be considered as in any way necessary Overlapping or overriding of the fragments even when relatively extreme and to a degree not to be permitted in similar fractures in later years can be entirely disregarded Such shortening of the bone as may result from union of the fragments in the presence of overriding can be depended upon to disappear during early childhood this being compensated for by such acceleration of the

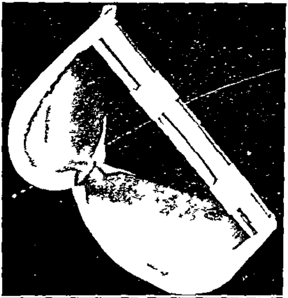

FIG 1033 (*Top*) Splint cut out of tin is folded to right angle at center Parts to be applied to trunk and thigh are bent transversely to fit individual patient and the two stems are bent to hold main arms at right angle Stems are supported by a piece of tongue-depressor of proper length placed beneath them and held by adhesive Entire splint is surrounded by adhesive plaster Sharp margins are protected by adhesive tape

FIG 1034 (*Bottom*) Splint cut by pattern suitably molded essential parts fixed in proper relation to each other and its margins protected is completed by a lining of piano-felt, held by a strip of adhesive

FIG 1035 Birth fracture of shaft of femur—Van Arsdale splint applied to thigh of newborn child Thigh is flexed at right angle to trunk and abducted Splint is held in position by means of a gauze bandage about trunk and about thigh, these bandages being reinforced with narrow circular strips of adhesive plaster. Portion of splint applied to injured thigh is somewhat longer than thigh itself, thus affording more satisfactory support to lower part of thigh and knee This splint provides suitable opportunity for application of diaper and for transportation of infant from place to place as may be necessary When in its cradle the baby's foot and leg may be supported with a small pillow or cushion for the dual purpose of the comfort that it provides and in order to favor circulation in lower part of extremity.

process of growth of the affected bone as may be required.

Union of the fragments in cases of birth fractures of the femur is usually complete in three weeks in the normal infant, and accomplished by means of an abundant production of healthy callus about the site of fracture.

The collaboration of the x-ray is of great value in the treatment of birth fractures of the femur, not only to reveal the conditions to be dealt with in the fresh fracture, and the degree of success attained in the first reduction of the fracture and the application of the splint, but to afford assurance that a satisfactory alignment of the fragments is being maintained throughout the process of repair.

It occasionally happens that union has been completed in these fractures with the fragments in a position of acute anterior angulation. Such cases, when followed with the x-ray, will show a gradual transformation of the angular deformity into an anterior curvature of the bone affecting that portion of the shaft originally containing the birth fracture (Fig 1037). It will also be noted that the site of this curvature will gradually come to occupy a position relatively higher up in the shaft of the bone due to the preponderance of the growth of the developing shaft of the femur at the inferior epiphyseal line.

In contrast to the humerus, which quite uniformly shows a complete disappearance of residual deformities following birth fractures of this bone during the first two years of life, deformities following birth fracture of the femur, due to failure to eliminate the original anterior angular deformity, while definitely diminishing, tend to persist to some extent throughout the entire period of growth This may be accounted for by the retarding effect of weight-bearing upon the injured bone, an influence coming into play very early, and continuing throughout childhood and after.

In a case of birth fracture of the femur

that had healed with an acute anterior angular deformity and was followed for more than 20 years, the x rays at the end of this period still revealed some thickening of the shaft of the bone in its upper part, some slight anterior curvature at this point, and some slight shortening of the leg as a whole, due probably to the slight curvature of the shaft of the bone While there was no functional disability of any sort whatsoever, there was still present in the follow up x ray distinct evidence of a birth fracture that had occurred 20 years before, and perhaps considered at the time a matter of little or no particular importance

FIG 1036 X ray of birth fracture of shaft of femur under treatment by means of a Van Arsdale splint It will be noted that long axes of fragments lie in planes parallel with each other even though fragments are overriding and considerably separated This represents a satisfactory reduction for a birth fracture of femur since when union takes place with fragments in this position outcome can be depended upon to be a straight bone soon becoming indistinguishable from its uninjured fellow of opposite side

BIRTH SEPARATIONS OF CARTILAGINOUS EPIPHYSES

It is probable that there have been separations of the epiphyses of certain of the long bones of the newborn child since the time that operative obstetrics was first introduced into the practice of medicine It is probable, also that these separations have always been and to some extent still are, mistaken for other more familiar injuries that present a somewhat similar clinical appearance Until the advent of the x ray there was no means available for differentiating clearly between a true dislocation and an epiphyseal separation in the newborn or of definitely eliminating the possible presence of a fracture of the shaft of a long bone in close proximity to a joint The information now contributed by the x ray amply supports the opinion that the dislocation of articular surfaces of the long bones composing the larger joints is a very rare, or possibly unknown birth injury, and indicates as well that the not infrequent birth injuries hitherto believed to be true dislocations are almost invariably separations of the cartilaginous epiphyses

That an epiphyseal line should be so devised as to part under the strain of operative delivery in order to spare the ligaments composing an important adjacent joint might be accepted as a clear manifestation of providential foresight By this arrangement

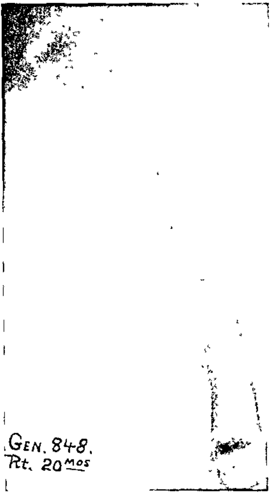

FIG 1037. Birth fracture of shaft of femur Fractures that have finally united in a position of anterior angular deformity, as displayed in Fig. 1031, soon become transformed into an anterior curvature of shaft of bone Since preponderance of growth of femur takes place at lower epiphyseal line, this deformity, which was originally near center of bone, gradually becomes higher and higher on shaft. Such deformities following birth fractures of femur, particularly in their more extreme degrees, ordinarily persist throughout childhood and adolescence.

the essential integrity of the larger joints is conserved, whatever the vicissitudes of childbirth, and the force brought to bear in the region of an important joint is absorbed by the yielding of the epiphyseal-diaphyseal union rather than by the rupture of essential ligaments which would lead to a dislocation of articular surfaces. While the actual birth dislocation of a larger joint, if unreduced, would almost certainly result in a permanently impaired joint, the ability of the end of the shaft of a long bone to reunite itself to its respective articulation-forming epiphysis assures a complete recovery from an important birth injury without disability.

When an epiphysis has been separated from the shaft of the bone to which it is normally attached, the consequences are in direct relationship to the type and degree of the violence causing the separation. The epiphysis may be merely detached but not displaced, the simplest form of epiphyseal separation. Or the epiphysis may be detached, temporarily displaced, and then regain approximately its normal position, either as a result of the handling of the limb in the course of the examination of the injury or of a formal attempt to reduce a recognized displacement.

In the more severe injuries, the epiphysis is not only detached from its shaft but also completely and permanently displaced, unless the nature of the injury is understood and an immediate reduction of the displacement is successfully accomplished by manipulation of the parts affected.

The epiphyses that are commonly susceptible to birth separation are those of the humerus (Figs 1038-1039) and femur. Such separations may occur under conditions similar to those causing fractures of the shafts of these bones. Fractures of the humerus and femur are produced when excessive strain is brought to bear upon the centers of their shafts in the course of an operative delivery, while separations of their epiphyses may occur when similar strain is applied to the region of their extremities.

The cartilaginous epiphyses of the full-term child are considerably more of an anatomic entity than is commonly appre-

ciated, occupying the clear areas seen in the x rays between the extremities of the long bones which indicate the location of the joints When the separation of an epiphysis occurs during the manipulation of an extremity in the course of an operative delivery, some structure can usually be felt to snap or give way After the birth of the child swelling is at once apparent in the region of the joint involved—elbow, knee, shoulder, or hip

The examination of an elbow presenting a diffuse swelling due to a separated lower humeral epiphysis will readily reveal the presence of abnormal mobility in the region of the elbow joint If the forearm is flexed to a right angle with the arm, and the arm held firmly in one hand and the forearm in the other, the examiner can readily produce an abnormal backward and forward mobility in the region of the elbow joint

When a separation of the lower femoral epiphysis is suspected (Figs 1042 1043), a corresponding method of examination applied to the lower extremity will determine the presence or absence of such an injury

As a separation of the upper humeral epiphysis usually occurs while dealing with the child s arms that have become extended above its head in the course of a breech extraction, the force producing the injury acts in a postero anterior direction The head of the bone remains in its normal position in the glenoid cavity, and the upper end of the shaft of the humerus, once it is torn loose at the epiphyseal line, is projected sharply forward, and so a very considerable prominence immediately appears

FIG 1038 (*Left*) Birth separation of lower humeral epiphysis While separation of lower humeral epiphysis is probably the most frequent of such birth injuries it often goes unrecognized X ray examination of an injured elbow in a newborn child may afford immediate evidence of a separated lower humeral epiphysis With forearm flexed at a right angle with arm, some backward displacement of bones of forearm with reference to long axis of shaft of humerus may be noted above, while the clear area representing the cartilaginous structures composing the elbow joint, may be narrowed down bringing bones of forearm closer to lower end of shaft of humerus

FIG 1039 (*Right*) Birth separation of lower humeral epiphysis In addition to backward displacement of bones of forearm and narrowing of joint space usually seen in x ray made soon after birth in cases of dislocation of lower humeral epiphysis it sometimes occurs that a small portion of lower end of shaft of bone may be torn away and more or less displaced along with cartilaginous epiphysis When this occurs the early and conclusive x ray diagnosis of this injury is greatly facilitated

at the front of the shoulder joint. This rather startling and hard-feeling projection is often attributed to a dislocation of the shoulder, a diagnosis seemingly supported by the fact that manipulation of the shoulder joint results in prompt and complete disappearance of the swelling, accompanied by the sensation of having reduced a dislocation.

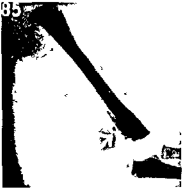

FIG. 1040 (*Left*) Birth separation of lower humeral epiphysis Some injury to adjacent periosteum is a constant feature of birth dislocations of the cartilaginous epiphyses, and by eighth day new bone has begun to form beneath periosteum thus stripped away from posterior surface of shaft of humerus. New-bone formation thus stimulated varies directly as degree and severity of periosteal injury.

FIG. 1041 (*Right*) Birth separation of lower humeral epiphysis. During first few weeks following birth dislocation of lower humeral epiphyses, new-formed bone about lower part of shaft of humerus will be seen in x-ray to increase in density. When separation of epiphysis has been followed by a persisting displacement of this structure, as much as necessary of a new humeral shaft is developed to connect once more this displaced epiphysis with shaft of bone to which it belongs and to eventually effect a complete anatomic restoration of entire bone which will show no evidence of birth injury in x-ray and become indistinguishable from its uninjured fellow of opposite side.

The upper extremity of the femur is the least frequently affected of the four large epiphyses sometimes separated as a result of birth trauma. More resistant to injury than the other epiphyses and deeply situated beneath groups of large muscles, it usually succeeds in surviving the stresses of even the more violent operative deliveries

Even when a separation of the upper femoral epiphysis has occurred, a diagnosis is somewhat difficult to satisfactorily establish. A considerable swelling is readily observed involving the upper part of the thigh and the region of the hip joint, and there is the usual pseudoparalysis of the extremity affected. While a false point of motion is present, this is situated too close to the hip joint itself to be helpful in arriving at an opinion as to the nature of the injury. The nature of the delivery, the operator's impression that some structure had yielded during the manipulation of the legs and buttocks, together with the appearance of the affected parts following delivery and the x-ray information, will all combine under ordinary circumstances to support a fairly conclusive diagnosis of separation of the superior femoral epiphysis.

The x-ray examination can usually be

depended upon to confirm without question the presence of a birth separation of a cartilaginous epiphysis It will also assist in making known the extent of the displacement of this epiphysis when displacement has followed upon the separation, and will exclude the existence of a supracondylar fracture of the humerus or femur when the physis As the lower femoral epiphysis is usually displaced posteriorly when dislocated a lateral view will show the nucleus within the epiphysis more or less posterior to the long axis of the shaft of the bone

In the case of the lower humeral epiphysis no bone nucleus being present, some departure from normal can be made out in

FIG 1042 (*Left*) Birth separation of lower femoral epiphysis In birth separation of lower femoral epiphysis location of epiphysis can be satisfactorily determined in x ray because of presence of ossification nucleus within epiphysis A departure from its normal position beneath shaft of bone is readily ascertained in newborn by means of x ray of knee joint, anteroposterior and lateral In this lateral view taken on tenth day epiphysis is thus shown to be displaced both backward and upward Extent to which periosteum has been torn away is also indicated by presence of new formed subperiosteal bone just beginning to make its appearance

FIG 1043 (*Right*) Birth separation of lower femoral epiphysis At two weeks new bone formation has progressed and by its extent anteriorly suggests lateral as well as posterior displacement of epiphysis Contours and position of epiphysis itself are well indicated by evidence of two of its boundaries clear area between bone nucleus and beginning of new formed bone above and clear area between bone nucleus and shaft of bone anteriorly representing areas occupied by cartilaginous portions of epiphy is located above and in front of nucleus

inferior epiphysis of one of these bones is involved, an injury often believed to have occurred and not infrequently confused with an epiphyseal separation Both immediate and late evidence of the separation may be obtained

In the case of the lower femoral epiphysis, the bone nucleus within the epiphysis is quite uniformly present in the full term child, and furnishes an immediate and reliable clue to the whereabouts of the epi the relationship of the shaft of the humerus to the bones of the forearm at an early x ray examination In a lateral view, with the forearm flexed to a right angle with the arm the articular notch of the ulna may be discovered to be posterior to its normal relationship with the long axis of the shaft of the humerus The clear space representing the cartilaginous articular structures will be seen to be reduced vertically, bringing the lower end of the shaft of the hu

merus into closer relationship with the bones of the forearm Furthermore, in the wrenching loose of the lower humeral epiphysis, one or more small particles of the inferior margin of the shaft of the bone are frequently torn away as well, thus producing a readily perceptible slightly ragged appearance in the normally sharply defined inferior margin of the shaft of the bone

FIG 1044 Birth separation of lower femoral epiphysis As in birth dislocation of lower humeral epiphysis, such new-bone formation as may be necessary to reunite displaced epiphysis to shaft of its bone is developed beneath periosteum stripped up from lower part of shaft of femur While new bone is being laid down to assist in formation of a new femoral shaft, superfluous portions of original shaft are being simultaneously absorbed (Cf Fig 1041)

With regard to the upper epiphysis of the humerus or femur, there may be evident in the anteroposterior x-ray, as immediate evidence of a separation of the epiphysis from the shaft of the bone, a fairly readily defined widening of the space between the upper end of the shaft and the bony surface with which the invisible head of the bone normally articulates, the glenoid cavity of the scapula or the lateral wall of the true pelvis.

The deferred and additional x-ray evidence of a birth separation of an epiphysis is afforded by the stripping up of the periosteum from some part of the adjacent shaft of the bone affected, the periosteum thus

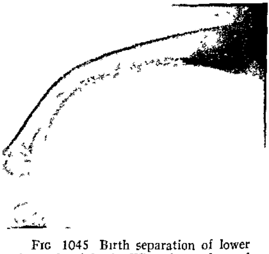

FIG 1045 Birth separation of lower femoral epiphysis When lower femoral epiphysis has been separated and displaced as a birth injury and repair has proceeded without replacement of affected part, an anterior curvature of lower part of shaft of femur develops, as shown in this x-ray at age of eight and one-half months, and which presents usual deformity of femur to be expected in cases of this injury under such conditions While anterior curvature developing after malunion of birth fractures of shaft of femur comes to occupy upper part of shaft of bone, that resulting from uncorrected displacement of lower femoral epiphysis occupies lower part of shaft, in each instance due to preponderance of growth of bone taking place at inferior epiphyseal line (Cf Fig 1037) Although curvatures sometimes resulting from birth dislocations of lower femoral epiphysis, such as that presented herewith, may be counted upon to decrease considerably during childhood and adolescence, they are likely to persist to some extent into maturity, causing more or less inequality of legs, tilting of pelvis, and even slight curvature of spine

disturbed reacting within the first week to ten days by a generous production of sub periosteal new formed bone Apparently the epiphyseal line gives way first upon the sur face primarily affected by the force pro ducing the injury, then, with continuation of the causative force, the epiphysis departs from its normal location carrying with it the periosteum attached to its opposite sur face, which is stripped from the shaft of the bone for a variable distance

In the case of the superior epiphyses, the new bone produced under such conditions is observed in the x rays surrounding the upper portion of the shaft in irregular fluffy appearing deposits while in the sepa ration of the inferior epiphyses there is usually noted a slender, wedge shaped de posit of subperiosteal bone occupying the posterior surface of the shaft of the affected bone to the same extent that the periosteum has been torn away

As the x ray manifestations of the birth separations of the epiphyses of the two most important long bones are peculiarly distinc tive and do not resemble other bone lesions in the newborn, they are particularly valu able from the standpoint of diagnosis in these injuries In the absence of a congenital specific infection and following an operative delivery, deposits of new bone appearing in the x rays after the end of the first week and situated in the region of the extremities of these bones may be accepted as due to an epiphyseal separation These deposits will vary greatly in amount, from no more than just sufficient to permit of a diagnosis, to profuse deposits extending along one half to two-thirds or more of the length of the shaft of the injured bone

The treatment of the separations of the epiphyses of the humerus and femur in the newborn consists principally in rest of the affected extremity When it can be deter mined that a displacement of the epiphysis has followed upon its separation, an attempt at the reduction of this displacement is in order This will apply particularly to the

FIG 1046 Birth separa tion of upper humeral epi physis While swelling about shoulder joint and a dan gling arm may suggest pres ence of separation of upper humeral epiphysis in new born child immediate con firmation of this diagnosis is not available by x ray ex amination This epiphysis contains no bone nucleus at birth, as does lower femoral epiphysis, and departures from anatomic relationships are difficult to determine in this region However, by eighth or tenth day appear ance of new formed bone be neath periosteum stripped away from upper part of shaft of humerus as a part of this injury is sufficiently characteristic at this time to establish a definite diagnosis of birth separation of this epiphysis

lower femoral epiphysis, which is so satisfactorily visualized in the x-ray that the displacement can be readily demonstrated when it exists, and the result of the attempted reduction can also be definitely

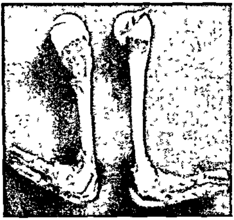

FIG. 1047. (*Left*) Birth separation of upper humeral epiphysis. A considerable contribution was made to investigation of birth separations of cartilaginous epiphyses by case of an infant born by means of a difficult operative delivery, presenting all the clinical and x-ray manifestations of separation of upper humeral epiphysis during its brief existence and finally affording an opportunity for direct examination of injured bone following death at seventh week Photograph of humeri obtained at autopsy in this case shows clearly the differences between injured and uninjured upper extremities of bones Lateral view of injured bone shows abnormal thickening of upper third of shaft, which had been source of characteristic x-ray findings from first week on, while epiphysis itself is shown displaced anteriorly and somewhat rotated as well.

FIG. 1048 (*Right*) Birth separation of upper femoral epiphysis. Probably least frequent of separations of cartilaginous epiphyses resulting from birth trauma, separation of upper femoral epiphysis may be identified in x-ray by two distinguishing features Some eight or ten days following operative delivery of child and in presence of considerable swelling about one hip and a lower extremity upon that side displaying complete absence of voluntary motion, x-ray examination revealed presence of new-formed bone about upper part of shaft of femur characteristic of a birth separation of a cartilaginous epiphysis It can also usually be demonstrated that upper part of shaft of femur is abnormally distant from lateral pelvic wall and acetabulum when compared with opposite and uninjured side.

ascertained. The unreduced, widely displaced lower femoral epiphysis is likely to be the cause of certain permanent deformities, which, however slight, are to be avoided whenever possible. This eventuality is not associated with the injury to the three other epiphyses.

In the case of the superior epiphyses, where it is impossible to determine with any degree of accuracy the relationship of the shaft of the bone to the epiphysis from which it has been separated, rest of the injured part for two weeks is all the treatment necessary The shoulder can be placed at rest by means of a Velpeau bandage, and the hip and knee can be satisfactorily held by means of a van Arsdale splint The separation of the lower humeral epiphysis can also be treated by the Velpeau bandage,

with the forearm in acute flexion, thus bringing the separated epiphysis forward

A separated epiphysis in the newborn child can be depended upon to unite with the shaft of the bone to which it belongs in two weeks time Even when it is considerably displaced, the deposits of new formed bone will immobilize the divided structures quite promptly preparatory to a satisfactory growth restoration, the lower femoral epiphysis excepted As in birth fractures of the humerus, residual deformities resulting from epiphyseal separations of the extremities of the humerus can be depended upon to disappear during the first two years of life Weight bearing apparently has its influence upon deformities following a birth separation of the inferior epiphysis of the femur with uncorrected displacement as it has in birth fractures of this bone

As the preponderance of the growth of the femur takes place at the inferior epiphyseal line and as this growth occurs from the epiphysis itself and not from the end of the shaft of the bone when separation of these structures has occurred, an epiphysis displaced backward will produce a deformity of the femur in the form of an anterior curvature This deformity, when considerable, will result in some shortening of the leg affected throughout childhood, but diminishing as adolescence comes on In one patient followed for 16 years there was still evidence in the x rays of the birth displacement of the lower epiphysis of the femur in the form of a slight persisting curvature of the lower part of the shaft of the bone, with slight shortening of the affected leg and with a corresponding slight tilting of the pelvis as a result of the inequality of the legs

For this reason the birth separations of the lower femoral epiphysis second in frequency to those of the lower humeral epiphysis, should be carefully looked for and investigated when, as a result of an operative delivery, such an injury may have occurred and if displacement is found to have occurred a well directed effort should be made to return the injured epiphysis as nearly as possible to its normal location

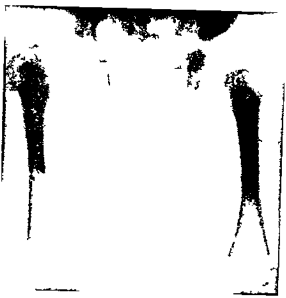

FIG 1049 Birth separation of upper femoral epiphysis Even before appearance of characteristic shadows about upper part of shaft of femur x ray may confirm diagnosis of birth separation of upper femoral epiphysis by indicating clearly lateral displacement of shaft of bone Best established at this time in its lesser degrees by comparison with opposite side, this displacement may at times be entirely apparent and obvious

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SECTION FOURTEEN

MILITARY SURGERY

44

Military Surgery

MAJOR GENERAL NORMAN T KIRK, SURGEON GENERAL, U S ARMY

AND

COLONEL LUTHER R MOORE M C

Part I

MEDICAL DEPARTMENT ORGANIZATION

Military surgery may be defined as the adaptation of the medicine and surgery of civil life to the needs of a military organization in peace and in war the objectives being the physical selection of the armed forces *the preservation of their health* the care and treatment of their sick and injured and the conversion of their casualties into replacements The Medical Department of the Army is a technical administrative and supply service and for the proper comprehension of the duties of a military surgeon a brief description of the organization of the Department and of its relation to other arms and services will be useful

TECHNICAL

The technical division of the Medical Department is charged with the preservation of the health of the Army This duty includes not only the professional care of its sick and wounded in peace and in war but also the performance of entrance physical examinations on all applicants for commissions and on all enlisted and civilian personnel of the armed forces annual physical examinations of commissioned personnel frequent physical examinations of the enlisted personnel and their re examination when they are separated from the service the institution of the necessary sanitary regulations immunization of the personnel against typhoid smallpox and tetanus and (in the case of troops in certain localities) against typhus cholera and yellow fever the prevention and control of communicable disease the instruction of the personnel in hygiene and first aid and the inspection of the food and water supply

ADMINISTRATION AND COMMAND

The Medical Department of the Army includes such organizations as hospitals medical supply depots hospital trains medical training camps and medical battalions and detachments In a maximum effort it may have under its command 25 per cent or more of the entire personnel in the theater of operations 15 per cent representing the sick and wounded in the hospital and 10 per cent or more being Medical Department personnel charged with their care and otherwise attached to the force

Staff Duties. The senior medical officer in a camp or post or the senior officer attached to an organization or a field force is designated as "the surgeon" In addition to his command duties in respect to Medical Department personnel he is also a member of the special staff of his commanding officer (line). As such, he advises the commanding officer concerning the health of the command and the efficiency of attached medical units. He assists in the selection of camp sites He makes frequent sanitary and technical inspections of the command. He submits recommendations on matters of policy affecting the medical service, and he prepares such portions of the projects and plans as pertain thereto. He keeps himself constantly advised as to the combat plans of his commanding officer, so that he may develop his own plans of action in ample time and submit them for approval. As a staff officer, he has only technical and advisory supervision of Medical Department units attached to subordinate organizations; he exercises no command over them.

SUPPLY

The Medical Department is responsible for the procurement, storage, and issue of all medical supplies necessary for the preservation of the health of the troops and the care and treatment of the sick and wounded. These duties include the procurement or construction and equipment of all hospitals, hospital trains, ambulances and other equipment used in the evacuation, treatment, and hospitalization of casualties.

PERSONNEL

The Medical Department is responsible for the procurement, training and assignment of the following classes of personnel:

1. Commissioned: Medical Corps, Dental Corps, Veterinary Corps, Sanitary Corps, Medical Administrative Corps, Army Nurse Corps, Physical Therapist Corps, Hospital Dietician Corps, and Pharmacy Corps.
2. Enlisted Medical, dental and veterinary services
3. Civilian: Dieticians, physiotherapy aids, clerks, and others

This personnel is dispersed in a field force by assignment to Medical Department units, attached to organizations, detailed as representatives, held as replacements, or detailed to civilian work or to work with relief societies. From tables of organization it is estimated that Medical Department personnel will constitute approximately 12 per cent of the aggregate military personnel required for a major effort.

The senior medical officer of a Medical Department unit is designated as the commanding officer. The senior officer of a detachment assigned to an organization is designated as "the surgeon" Other officers are assigned as assistants The dental officer practices his specialty and serves as a technical assistant in supply The veterinary office inspects food, cares for sick and wounded animals, is assigned to a veterinary installation, or commands a veterinary hospital, veterinary detachment, or other veterinary organization Sanitary officers, who are sanitary engineers in civil life, aid in the construction of installations and act as advisors in the various sanitary problems of the command Medical administrative corps officers, who have no professional training, are assigned as mess officers, adjutants, or assistants in supply, or perform similar duties.

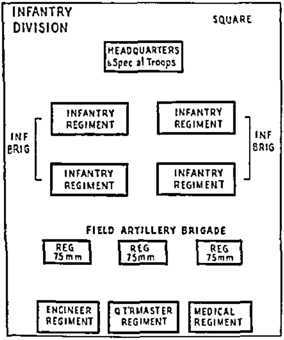
MEDICAL SERVICE WITH AN INFANTRY DIVISION

The medical service of an infantry regiment is the backbone of the medical service of the fighting troops A thorough understanding of the tactical employment of medical troops requires a good working knowledge of the tactics of the line troops to which they are attached, this means that a medical officer with an army in the field must be trained in military affairs in order

properly to care for and evacuate the wounded soldier

An infantry division is the smallest army unit which is self-contained It has a strength, roughly speaking of some 15,000 officers and men There are no animals For major operations two or more infantry divisions (usually three) are attached to each army corps Three army corps plus corps and army troops, make up a field army, the total strength of which, not including general headquarters reserve units, is approximately 230 000 officers and men The strength of a corps consisting of three divisions aggregates approximately 50,000 officers and men

The infantry regiment (Fig 1052) forms the basis of the fighting and holding force of the division It is supported by artillery, aviation, and other mechanized units It consists of a headquarters company, service company cannon company antitank company, and three battalions of four companies each In each battalion are a headquarters company, three rifle companies, and a heavy weapons company



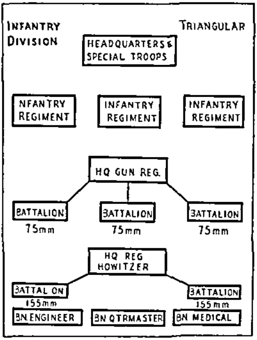
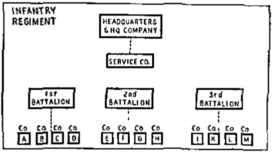


Fig 1050 (*Left*) Infantry division (square) diagrammatic organization Strength of this type division in World War I was some 22 000 officers and men All organization equipment is animal drawn number of animals almost equaling number of men in division National Guard and regular Army units in insular possessions are still so organized This type division is self-contained and therefore able to operate independently

Fig 1051 (*Right*) Infantry division (triangular) diagrammatic organization War strength is approximately 11,500 officers and men and there are no animals in the division Troop, equipment and supplies are moved by truck Artillery is motor drawn It is so organized that it may be divided into three combat units—i e one regiment of infantry, one battalion 75 mm guns supported by a section of 155 mm howitzers Divisional medical support is materially reduced and becomes dependent upon corps medical regiment for support

The regimental medical detachment of an infantry regiment (Fig 1053) consists of

one major (regimental surgeon), eight captains or lieutenants (three of whom will be designated as battalion surgeons), one dental surgeon, and 126 enlisted men. This



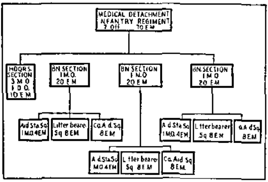


FIG. 1052. (*Top*) Infantry regiment, diagrammatic organization. Strength of new infantry regiment in both square and triangular divisions is same—approximately 2,500 officers and men Fire power is increased by new semi-automatic rifle, although actual number of rifles has been decreased. Regiment is transported by truck from corps or army pool or proceeds by marching

FIG. 1053. (*Bottom*) Diagrammatic representation of infantry medical detachment. Each medical detachment is commanded by a major, medical corps, the regimental surgeon, and is organized into a headquarters section and three battalion sections, as is the infantry regiment, and are so attached.

detachment is commanded by the surgeon and administered as a company. For tactical purposes it is organized into a headquarters section and three battalion sections.

The surgeon is responsible for the health of the regiment, the retention of the physically fit, and the collection and evacuation of the sick and wounded.

Space does not permit detailed mention of the duties of detachments in camp, on the march, or on reconnaissance to obtain information concerning territory to be occupied or to select sites for regimental and

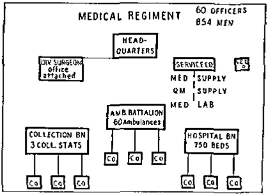


FIG. 1054. Medical regiment, diagrammatic organization. This organization was developed after World War I One was assigned to each division, one to each corps, and one to each army. It replaced the "sanitary train" of World War I. It still forms a part of the square division and as a corps medical regiment supplements and supports the "triangular" division's medical battalion It is motor-drawn throughout. A medical squadron, smaller organization, forms a part of each cavalry division.

battalion aid stations preceding and during combat. Each problem is changed in attack, in defense, or when retrograde movements occur.

The surgeon, with the headquarters company, establishes the regimental aid station in the vicinity of regimental headquarters, choosing a site which is as sheltered as pos*sible and is protected from rifle fire Each* battalion section follows into action the infantry battalion to which it is attached and establishes a battalion aid station. Eight aid men leave the battalion and two accompany into action each particular infantry company to which they are attached.

The equipment of the regimental and battalion aid stations consists chiefly of litters splints blankets surgical dressings drugs and food It is carried on quarter ton trucks (jeeps) with quarter ton trailers Two jeeps are allotted to each battalion section and one to the regimental headquarters section The regimental headquarters is also allotted a 2½ ton truck which carries the baggage of the officers of the detachment and which is designated as the R and B truck During combat it is frequently necessary and convenient to move aid station equipment by hand

Battalion surgeons make frequent reports of casualties to their commanders and to the regimental surgeon When an advance occurs the station is closed the wounded remaining behind with proper attendants and the aid station squad advances with its battalion Supplies are replenished by the litter bearer section of the collecting battalion

Aside from the preservation of the morale of fighting troops by early medical attention to and prompt removal of the wounded the functions of the regimental detachment in combat are

1 The location tagging sorting and separation of the disabled from the able

2 The collection of casualties at aid stations where emergency treatment is given and from which the physically fit are returned to the front Gas casualties are segregated

3 Examination of the dead and sanitary supervision of their disposal

4 Preparations of records of the sick wounded and dead who have been seen or treated by the detachment

The Medical Battalion

The organization of a medical battalion (Fig 1055) consists of a headquarters and headquarters detachment three collecting companies and one clearing company The commanding officer of the medical battalion serves in a dual capacity (1) as the division surgeon in which role he is a member of the special staff of the commanding general of the division having technical supervision of all Medical Department units in the division and (2) as commander of the medical battalion directing its activities through his executive or plans and training officer

Medical battalions are also assigned to the corps and the army Here they serve the troops in the corps and army areas or

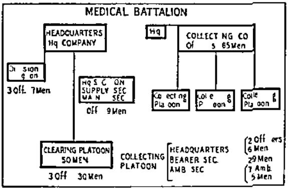


Fig 1055 Medical battalion diagrammatic organization A recently organized medical department unit replacing medical regiment in triangular division Its mission is to care for casualties of this division for first 48 to 72 hours unaided Its collecting company is so organized that it may be divided into three like sections so as to serve the three combat teams of the triangular division when operating independently

assist the medical battalion of the division as ordered by the army or corps commanders

The medical battalion is responsible for the evacuation of wounded from the battalion and regimental aid stations to the clearing station which it operates and from which depending on their condition patients are sent to the field hospital located in close proximity to the station or to an evacuation hospital in the army area

The collecting company consists of a headquarters a litter bearer section and a collecting station section A given company evacuates casualties from the battalion and

regimental aid stations of the regiment which it is ordered to support. Patients are brought by hand litter or wheel litter from

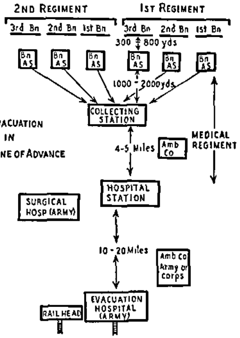


FIG. 1056. Diagrammatic representation of employment of divisional and army medical department installation in evacuation of casualties in zone of advance.

Battalion-aid stations established by regimental medical detachment.

Collecting station
Hospital station
Ambulance company } Units of medical regiment which complete divisional evacuation and perform this function in divisional area. (Medical battalion performs a similar function in triangular division.)

Surgical hospital (army unit) established in divisional area and operated by army medical department personnel

Evacuation hospital (army unit) established by army in army area.

Ambulance companies. Army or corps which evacuate casualties from surgical hospitals and hospital station to evacuation hospital.

the aid stations to the collecting station, which has been established by the collecting-station section 1,000 to 2,000 yards behind the front line When possible, this station is sheltered from rifle and artillery fire and is located near water and near a good road going toward the rear It is supplied with tentage, mess facilities, splints, drugs, litters, blankets, and similar supplies in greater amount than at the battalion and regimental aid stations, but it has no beds.

THE AMBULANCE PLATOONS OF THE COLLECTING COMPANIES, each of which has ten ambulances, evacuate wounded from the collecting station to the clearing station established by the clearing company. On return trips to the clearing station each ambulance returns in kind such Medical Department equipment as blankets, litters, splints, and dressings which were used in the transportation of the last load of casualties to the clearing station.

The clearing company consists of two platoons, each provided with tentage sufficient to shelter about 100 patients A triage or sorting of casualties is now begun as the wounded are received from the front by ambulance or (if their wounds are slight) under their own power At a clearing station the following departments are established:

1 RECEIVING. Here the patients are admitted, examined, recorded, classified, and distributed

2. SURGERY. Here only minor surgical measures are instituted—chiefly the control of hemorrhage and the adjustment or reapplication of splints and dressings.

3. SHOCK Patients in shock are immediately put to bed, and correction of the condition is begun

4. GAS. Departments or wards are established as necessary if establishment of a separate hospital is not required, and treatment is begun.

5. NONTRANSPORTABLE. All patients who because of the nature of their wounds would stand transportation poorly are placed in this department, if a field hospital has been established near by, however, they are transferred to it immediately.

6 EVACUATION DEPARTMENT OR WARD All patients not requiring further hospitalization are at once returned to their organizations for duty All patients fit for immediate transportation farther to the rear are temporarily housed Patients originally admitted to surgical shock or other departments eventually arrive in this department if they survive their injuries, and are fed housed, and otherwise cared for here until they are evacuated by the corps or army ambulances to the evacuation hospital

Field Hospitals Of great usefulness in the management of the seriously wounded in this war have been the field hospitals attached to the clearing stations Each field hospital is composed of three platoons Each platoon, when reinforced by surgical teams is so stafted and equipped that it can function as a highly mobile independent hospital unit By the placement of a platoon of a field hospital in close proximity to the divisional clearing station surgical care as far forward as is compatible with the performance of surgery of acceptable standards is provided for patients with serious wounds of the chest and abdomen who could not withstand transportation In effect well equipped well staffed operating rooms are brought to the divisional areas and the risk of evacuating critically wounded patients to army areas several miles in the rear of the clearing stations is avoided Highly qualified surgical teams (thoracic, general surgery, shock teams) are employed to reinforce the personnel of such installations in the performance of the specialized surgery required for the e casualties

EVACUATION HOSPITALS

Twelve evacuation hospitals, each with a capacity of 400 beds, are allotted to each type army One ho pital is assigned to each division (old type), and three are held in reserve These hospitals are moved by truck and are usually established some five to ten miles from the battle front Tentage or existing buildings are used, and the location is at a point at or near where roads leading from the battle front and roads or railroads lead to the rear

At the evacuation hospital transportable casualties (in contrast to the nontransportable casualties treated in the field hospitals) receive their first medical and surgical care Patients are checked in, their records are instituted, their clothing is removed, they are bathed when possible, and they are sorted The chiefs of the surgical and medical services examine all patients on admission, classifying them as to the severity of their wounds and directing their disposition according to their condition The physically fit are sent to the adjacent convalescent (army) hospital Slightly wounded, slightly sick, and venereal patients are sent to the dressing and examining station and thence to the convalescent hospital The seriously wounded are usually admitted first to the shock ward where if they are in shock or in impending shock, they are treated by the standard regimen for shock and then sent to surgery via the x ray department All patients in this group eventually reach the operating room Roentgenologic or fluoroscopic examination is routinely performed on patients going to the operating room and the films are forwarded with the patient to the operating room or a written report is sent, accompanied by a diagram showing such details as fractures and the numbers and location of foreign bodies

As in the case of the field hospital platoon working in conjunction with a clearing station the evacuation hospital may call on auxiliary surgical groups to furnish additional teams to supplement its own staff in periods of intense activity or when an unusually large number of cases requiring specialized surgical care is admitted to the hospital

Patients are sent from surgery to the postoperative wards, where they are treated until their condition is such that they may safely be evacuated to a general hospital for further care The period of hospitaliza-

tion depends upon the military situation, the type of the patient's injury, and available transportation facilities. It varies from a few hours to several days. When the hospital load approaches its bed capacity, when there are sufficient patients physically fit for transportation to fill a hospital train, or when an offensive is in progress and new casualties are expected, the commanding officer advises the army surgeon and requests evacuation.

Convalescent Hospitals (Army Unit)

A convalescent hospital with a capacity of 3,000 patients is established in the neighborhood of the group of evacuation hospitals serving a given army. It receives slightly wounded and convalescent patients from the evacuation hospital, and it treats venereal patients. It thus relieves evacuation and other hospitals, lessens further transportation to the rear, and at the same time retains this group of patients under the army, to which, therefore, they can be returned to duty at the earliest practicable date.

Hospital Trains

Hospital trains in war time consist of 16 cars and have a capacity of 360 patients each. Ten cars are ward cars, and six are used for train personnel, stores, supplies, mess, pharmacy, operating room, and similar purposes. These trains are used in the communication zone to evacuate patients from the evacuation to the general hospital. They are administered under the surgeon of the field force.

General Hospitals

General hospitals, whose capacities are variously 1,000, 1,500, 2,000 or more beds, are located in the communication zone of the theater of operations, far to the rear in so far as hostilities are concerned, or in the Zone of the Interior if hostilities are occurring in home territory. When the situation demands, three or more of these general hospitals may be grouped into a hospital center. When they are so grouped, given hospitals may specialize in particular types of cases (thoracic, neurosurgical, plastic, etc.), which will usually be found to be more satisfactory than having all cases handled indiscriminately in all hospitals

The treatment at general hospitals is essentially reparative surgery (q.v.) and is directed toward returning the patient to duty as promptly as possible if his condition is such that this purpose can be achieved within the period of time set by the theater evacuation policy. Patients requiring longer periods for complete recovery or requiring specialized types of reconstructive surgery are evacuated to general hospitals in the Zone of the Interior In this zone centers have been designated for such surgical specialties as thoracic surgery, plastic surgery, neurosurgery, amputation, ophthalmologic surgery, and vascular surgery. Centers have also been created for the treatment and rehabilitation of blind and deaf casualties

Medical-depot Company (Army Unit)

One medical-depot company is assigned to each army It is moved only by rail or water, and it is usually located in the army area, just to the rear of, or otherwise adjacent to, the evacuation hospital. It must be accessible to motor trucks of the army medical installations, as well as to medical battalions of the army, corps, and divisions. It is so organized that it may be subdivided into three platoons which may be established at different points in the army area. The supplies maintained in these depots are limited in character and amount to those essential to maintain combat efficiently for a period not to exceed three days Replenishments are received daily or as required from medical depots in the communication zone.

ORGANIZATION IN A FIELD FORCE

A maximum military effort necessitates

that a force of approximately 1 000 000 men will be mobilized and organized into four armies

The theater of operations is the area occupied by a military force at war During World War I it extended from base seaports in France to the Meuse Argonne In World War II the European Theater of Operations prior to the invasion of Normandy was contained in the British Isles Following the invasion of France and the establishment of General Headquarters (G H Q) in that country, the theater extended from the base seaports to the long and circuitous front which continued to alter as the front was moved forward from France into Belgium, the Netherlands Luxembourg and then on to German soil first west of and then east of the Rhine

The theater of operations is subdivided into a combat zone and a communication zone The former is occupied by the military forces in combat with the enemy and is subdivided into army areas (Fig 1057) The communication zone extends from the base port in an overseas expedition up to the army areas forward In fact, the sea, from the home port in the Zone of the Interior to the base port overseas forms a part of the communication zone The communication zone contains the organizations of the service of supply to the armies forward The commanding general of an expeditionary force establishes a general headquarters in this zone, usually in an advance section just behind the combat zone The office of the surgeon of the field force is located at this general headquarters

The organization in a field force is as follows

1 The Chief Surgeon (four medical officers are detailed as liaison with the general staff sections, which are G H Q (G 1) Personnel Sanitation, Red Cross, (G-2) Intelligence, (G 3) Operation and Training Troop Movements, (G-4) Hospitalization)

2 Deputy Chief Surgeon

3 Professional consultants

4 Chief Veterinarian

5 Chief Dental Officers

6 Other assistants as required

Medical Department Concentration Centers Other medical units under con

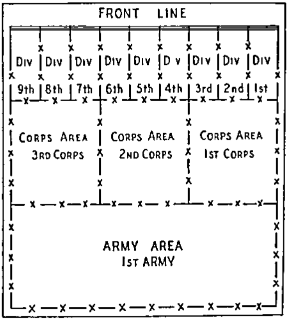


FIG 1057—Army area Diagrammatic representation of a type army in combat showing its organization and disposition of its assigned troops This is a geographic area which will be 10 to 20 miles in depth Its width will depend upon resistance met or expected and it may be flanked on either side by two other armies a mountain range or neutral boundary Its boundaries will be limited by orders and so indicated on a military map In depth it comprises the zone of advance and immediately in its rear is the zone of communications the two zones being known as the theater of operations

trol of the Chief Surgeon are usually concentrated in and administered by the Medical Department Concentration Center in the communication zone They consist of the following installations

1 Medical Department Concentration Center

2 Evacuation hospitals, staging or in reserve

3. Auxiliary service groups, or professional service detachment.

4. All Medical Department casuals and replacements, including officers, nurses, and enlisted men.

5. All units after coming from the front that may be organized, equipped, and reassigned, or are overhauled and refitted before further assignment.

Medical Department Concentration Centers and Professional Service Detachments are authorized at the rate of one per army. The teams which constitute them are employed at hospitals in the combat or communication zone to augment their personnel as needed. They are especially selected for their professional ability and are so organized that they can be sent fully equipped for work on short notice. There are in these groups:

24 surgical teams
6 orthopedic teams
6 shock teams
6 gas teams
4 maxillofacial teams
4 neurosurgical teams
4 thoracic-surgery teams
3 dental-prosthetic teams
4 miscellaneous teams.

The personnel of the teams is as follows:

SURGICAL. 1 operator (surgeon), 1 assistant (surgeon), 1 anesthetist (preferably a medical officer), 1 nurse, 2 enlisted specialists.

ORTHOPEDIC. 1 officer (orthopedist), 1 nurse, 2 enlisted specialists.

SHOCK. 1 officer (medical), 1 nurse, 2 enlisted specialists.

GAS. 1 officer (medical), 2 nurses, 2 enlisted specialists.

MAXILLOFACIAL. 1 neurosurgeon, 1 assistant (surgeon), 1 anesthetist (nurse), 1 surgical assistant (nurse), 1 enlisted specialist (dental mechanic), 1 enlisted specialist (surgical technician).

NEUROSURGICAL. 1 neurosurgeon, 1 assistant (surgeon), 1 anesthetist, 1 nurse, 2 enlisted specialists.

THORACIC. 1 thoracic surgeon, 1 assistant (a thoracic surgeon whenever possible), 1 nurse, 2 enlisted specialists.

DENTAL-PROSTHETIC. 1 prosthetist, 3 enlisted specialists.

MISCELLANEOUS All Medical - Department casuals and replacements, whether officers, nurses, or enlisted men.

THE THEATER SURGEON

The medical activities of a theater of operations are in command of a general officer selected by the commander of the field forces. The function of the forces in the communication zone, under orders from G.H.Q., is to supply the armies in the combat zone. Food, ammunition, and supplies are procured, stored, and shipped forward by rail. Replacements are quartered, trained, equipped or refitted, and transported. Sick and wounded are evacuated from evacuation hospitals to general hospitals which have been made available by construction or lease and which are equipped, staffed, and operated by the personnel assigned to this zone.

The theater surgeon is responsible to the commanding general of the theater for the care of all sick and wounded in his theater His office is organized on a functional basis into various sections as follows:

1. Administrative
2. Operations
3. Hospitalization and evacuation
    a. Procurement, construction, and operation of all mobile and fixed hospitals
4. Supply
    a. Statistics and requirements
    b. Procurement, storage, and distribution
    c. Finance, accountancy, and disbursing
5. Personnel (officers, nurses, enlisted personnel, civilian employees)
6. Sanitation
7. Vital statistics
8. Professional consultants

9 Dental
10 Veterinary

Medical Installations in Communication Zone

The medical installations in a communication zone consist of

1 Hospital centers three or more general hospitals
2 General hospitals 1 000 1 500 or 2 000 beds each
3 Convalescent camps 1 000 beds each One camp is allotted to each hospital center
4 Station hospitals 25 to 900 beds each
5 General dispensaries as indicated
6 Medical laboratories (general) for research, sterilization of sera etc
7 Medical laboratory 1 per army
8 Veterinary units general and stations hospitals and food inspection teams
9 Medical supply depots
10 Hospital trains

Consultant Section

Each theater surgeon has on his staff surgical consultants in medicine and surgery who are assisted in turn by medical officers qualified in various specialties The surgical specialties include anesthesia neurosurgery thoracic surgery plastic surgery orthopedic surgery etc

The theater surgeon s consultants are responsible to him for the maintenance of the highest possible standards of professional care for the sick and wounded in the theater and to fulfill this purpo e they obviously must be very well qualified from both the administrative and the professional stand point It is their duty not only to appraise and critically evaluate the care afforded the wounded in the theater and to offer constructive suggestions thereon but also to utilize to the fullest advantage by proper organization and assignment the specialized personnel in the theater

The importance of the work of these consultants and their assistants in special theaters of operation cannot be overestimated Moreover it is largely on the basis of careful study of their observations that policies are formulated in the Office of the Surgeon General for the care and evacuation of sick and wounded patients throughout the Army

HOSPITAL BED REQUIREMENTS

Many factors enter into the consideration of hospital bed requirements including the distance from home territory the severity of the fighting expected the climatic conditions and the duration of hostilities Requirements for a given theater of operations are expressed in terms of the total fixed beds believed to be required rather than the number of units Only beds established in fixed hospital units designated to furnish definitive care are considered Beds in mobile evacuation and surgical hospitals or medical regiments are not included in these calculations

The following figures are based on the experience of the Medical Department during the last half of 1944 in the European Theater of Operations

Nonbattle Casualties The daily admis s on rate to hospital of seasoned troops and nonbattle casualties was 1 0 per 1 000 The average stay in hospital in this group would have been about 20 days under a 120-day evacuation policy The total average days including time spent in the Zone of the Interior (Z I) by evacuated patients would be about 25 days Treatment beds required may therefore be estimated as follows

		Average Days in Hospital			*Beds Required per 1 000*	
Daily Admission Rate per 1 000		Theater	Theater and Z I		Theater	Theater and Z I
1 0	×	20	25	=	20	25

Allowing 20 per cent additional beds for dispersion, 2.4 per cent of theater strength might well be the required number of beds in the theater for nonbattle cases, and 3.0 per cent in the theater and Z. I.

For every 1,000 nonbattle cases admitted to hospital (in a theater operating under similar conditions) about 1 would die, 42 would be invalided home, and 957 be returned to duty in the theater.

Battle Casualties. During the last six months of 1944 in the European Theater the daily battle-casualty admission rate averaged about 0 6 per 1,000 men per day. The average duration of treatment in the theater under a 120-day evacuation policy would have been about 48 days as compared to about 94 days for total treatment required in the theater and Z. I. Beds required in the theater for these cases would thus be:

$$0.6 \times 48 = 28\ 8 \text{ per } 1{,}000,$$

and total beds in the theater and Z. I. would be:

$$0\ 6 \times 94 = 56.4 \text{ per } 1{,}000$$

Allowing 20 per cent additional beds for dispersion would give bed requirements of about 3 5 per cent of theater strength in the theater and about 6 8 per cent in the theater and Z. I.

For every 1,000 battle-casualty cases admitted to hospital about 30 would die, 230 would be invalided home and the remainder, 740, would be returned to duty in the theater. Of those returned to duty in the theater about 260 would be returned in the first 30 days and 275 within the following 30 days. Cases invalided home, about 23 per cent of the total, are permanent losses as military assets to the theater.

Casualty Estimates

Nonbattle Cases. In campaign with seasoned troops, except in a particularly unhealthy area, the average daily rate of admission for infantry-division cases requiring 24 hours or more of treatment may average in the neighborhood of 3 per 1,000, or 0.3 per cent of division strength Of this number about two-thirds will require hospitalization, while the remaining one-third may be treated in quarters, depending on climatic conditions, changes in the tactical situation, and other factors. Both the rate of admission and the proportion of cases requiring hospitalization will vary considerably.

Battle Casualties. The rates experienced will vary widely, depending upon resistance met and upon whether offensive, defensive, or retrograde movements are employed During World War II the relative proportions of wounds caused by high-explosive fragments and by bullets differed markedly for different types of combat In Europe about three-quarters of the wounds were caused by high-explosive fragments and about one-quarter by bullets. In the Leyte and Saipan invasions, on the other hand, about half the wounds were caused by bullets and half by high-explosive fragments.

The daily percentage of battle casualties for a division in a severe engagement may run as high as 2 to 3 per cent of strength The average daily rate experienced by infantry divisions in World War II during the entire European campaign (June 6, 1944 to May 8, 1945) was slightly over 0.2 per cent of strength

The ratio of killed to wounded was about one to four, although the ratio differed between theaters and for different types of operations.

Excluding those killed in battle, approximately one-half of all casualties are litter patients

In estimating battle casualties in an army, an estimate based on the number of divisions actually engaged will usually be more accurate than one determined by using a rate for a corps or army, since the make-up of the corps and the army is much more subject to change with changes in the tactical situation than is that of a division.

Included in the total casualties to be

cared for are those of the enemy left on the field

Transportation Requirements The transportation requirements for the wounded of a division of 15 000 having a 2 per cent casualty rate per day may be estimated for that day as

	Per cent	Number
Dead	20	60
Ambulant wounded	40	120
Litter wounded	40	120
	100	300

Of the 120 litter wounded perhaps 2 per cent or two cases would be nontransportable beyond the surgical hospital leaving the number to be evacuated by the army from the division by ambulance

Litter patients	118
Sitting patients	120
Total	238

ARMY AND CORPS

Each army and each corps has its surgeon who is on the special staff of the general commanding and who is responsible for the supervision of the technical and supply functions of all Medical Department personnel and organizations serving therein The organization of Medical Department units assigned to a type army is as follows

1 ambulance company 1 collecting company and 1 clearing company for each of the component divisions of the corps and of the army

2 field hospitals for each 3 divisions

1 evacuation hospital (400 beds) for each component division and 1 evacuation hospital (750 beds) for each 3 divisions

1 veterinary evacuation hospital for each cavalry division

1 convalescent hospital (3 000 beds) for each type army

1 medical-depot company for each type army

1 medical laboratory for each type army

The office of the staff of the army surgeon is divided into eight sections including administration operations hospitalization and evacuation supply sanitation consultant dental and veterinary The administrative staff consists of an executive and planning officer with one assistant a medical inspector a personnel officer with one assistant a liaison and intelligence officer an adjutant and a chief nurse

The corps surgeon of each army corps has similar functions within the corps His staff is similar though much smaller and the Medical Department units in his charge are fewer than those in charge of the army surgeon

Part II

PROFESSIONAL CARE OF THE WOUNDED

By Major General Norman T Kirk

The chief difference between military and civilian surgery aside from certain important therapeutic modifications necessary as a matter of expediency is in the circumstances under which therapy must be applied The chief of these differences has to do with the manner in which the patient reaches the hospital In civil life this is no problem at all The patient reaches the hospital within a short time after his injury or illness and is operated on without delay at the institution to which he is first taken

The first principle of military surgery on the other hand is that a disabled soldier must be got out of the way of battle as promptly as possible When once he loses his military usefulness his unit must advance without him and he is not permitted to hold it back From his own standpoint this consideration is not as cold blooded as it might seem at first glance for the accumulation of wounded men in forward areas

would militate against their own effective medical treatment For the sake of his own welfare, therefore, as well as for military reasons, the wounded soldier, however serious his wound, cannot receive any but strictly emergency treatment until he reaches a point at which his treatment will not interfere with military procedures and at which surgery can be properly performed.

Another important difference between military and civilian practice, and one which dictates the modifications in therapeutic methods already referred to, has to do with the observation of the patient. In civilian life the patient is observed after operation by the same team which examined him before operation, decided upon the method of treatment to be employed, and then operated on him. In military practice continuous observation of the patient by the same team is not possible in any of the forward echelons. The wounded man is seen by several different observers before he reaches the hospital, is operated on by another team, and may be cared for after operation by still another team. Certain procedures which are standard and safe in civilian practice—notably primary suture of wounds following débridement—are not safe in military practice because of the lack of continuous observation of the patient by the same surgical group

The objectives of military medical care are twofold: the salvage of life and limb and other functional salvage, and the rehabilitation and prompt return to duty, within as short a time as possible, of as many soldiers as possible, in order that the effective fighting strength of the Army may be maintained. The restoration to usefulness in civilian industry and society of those men who cannot be returned to useful military service is, from a strictly military standpoint, an incidental objective, though naturally it is pursued with equal earnestness.

The organizational aspects of the care of the wounded have been considered elsewhere in this chapter and will be touched upon in the following discussion only in so far as is necessary to make clear the various steps in the medical care of a wounded soldier from the moment he receives his wound on the battlefield until he is submitted to reparative procedures in a general hospital well behind the forward area It should be emphasized, however, that the process of evacuating a wounded man from the battlefield to an installation in the rear is not to be regarded as an assembly line at each point of which he receives part of his treatment, but rather as a conveyance line along which his condition is repeatedly checked and at each point of which measures are applied to render him transportable farther to the rear. The various halts in the process of evacuation are not for organizational or mechanical reasons. They are to insure that the wounded man is in suitable condition to continue his journey to the rear, and to improve his condition if it should not be immediately suitable

As in all surgical states, the wounded man's chances of survival and of functional salvage are increased in proportion to the speed with which he reaches the operating table after he has sustained his injury, and also in proportion to the adequacy of first aid and resuscitative measures applied to sustain him until that time Records of the Army Medical Department show that the time lapse between wounding and first aid care at the end of World War II did not usually exceed ten minutes, while the time lapse between injury and emergency surgery at an evacuation hospital was usually well under ten hours

The management of war wounds[1 3] may be divided into three phases: (1) initial surgery, which is concerned with the preservation of life and limb and which includes resuscitative as well as emergency operative measures, (2) reparative surgery, which includes surgical procedures in special fields and the secondary closure of wounds; (3) reconstructive surgery, which is essentially

plastic surgery Initial and reparative surgical procedures are performed in the hospital installations of a theater of operations Reconstructive surgery, with occasional exceptions is performed in general hospitals in the Zone of the Interior

TREATMENT PRIOR TO ADMISSION TO FIRST HOSPITAL

The transportation of a wounded soldier from the battlefield to an evacuation hospital consists of the following steps

1 First Aid on Battlefield During the active phase of an engagement, combat troops, who have themselves been instructed in the elementary principles of first aid to be applied to themselves or to their injured comrades, are accompanied into battle by company aid men Wounded men are often scattered over a large area and must be sought on the battlefield if they cannot remove themselves from it When a casualty is summoned by or found by a company aid man, he is given morphine splints or tourniquets are applied as necessary, the wound is covered with sterile gauze to prevent further contamination, and a plasma transfusion is begun if he is in shock or if the seriousness of the wound suggests that he is likely to go into shock Chemotherapy on the battlefield has been discontinued as of no value (See Chapter 22)

A tourniquet, once properly applied, is not removed, it having been found that leaving it in situ for periods as long as eight hours is not dangerous as was once thought As a matter of fact, it has been found that the periodic release once practiced contributed to the death rate, for the continued loss of small amounts of blood which occurred each time the tourniquet was released might cause irreversible shock in a patient already in shock as the result of a large loss of blood prior to its application

The position of the wounded man is indicated before the aid man leaves him, and he is tagged with a card which shows his name and organization, the wound or illness causing the casualty, the time and date and the treatment given

2 Transportation to First Aid Station Litter bearers who follow immediately behind the company aid men remove casualties from the battlefield by hand or litters and direct the walking wounded to the aid station Patients in shock are transported with the foot of the litter raised

3 Treatment at Battalion Aid Station Treatment at this point is limited to absolutely necessary measures such as the control of hemorrhage, more adequate splinting of fractures, readjustment of dressings, additional shock therapy including additional plasma and resuscitative measures Slightly wounded soldiers who need only minor treatment are cared for at the battalion aid station and are immediately returned to their units

A medical officer at this station determines priority of evacuation to the rear on the basis of available facilities in relation to the type and seriousness of the wound and the patient's condition Similar priority of evacuation is determined at each of the successive points of transport to the rear

4 Treatment at Collecting Station At this point the patient is again examined and additional emergency measures including plasma, are applied as indicated When sufficient casualties have been collected to fill one or more ambulances the patients are evacuated to the clearing station

5 Treatment at Clearing Station Here the wounded are carefully examined and sorted out (triage) into the following categories

Patients in Actual or Impending Shock These are at once admitted to the shock section and are vigorously treated before being evacuated further unless they are immediately sent to the field hospital attached to the clearing station for resuscitation and surgery The therapy of shock includes the administration of morphine as necessary for pain, positional treatment

(elevation of the foot of the bed), provisions against the loss of body heat, and the transfusion of additional plasma or, if indicated, of whole blood.

PATIENTS ENDANGERED BY TRANSPORTATION. Patients whose wounds are of such a character that further transportation without surgical attention would place them in jeopardy are admitted to a field hospital located in close proximity to the clearing station Here emergency surgery is performed, and they can be kept after operation until their condition permits further movement to the rear. A particularly important group of patients in this category are those with thoracic wounds which produce marked alterations of cardiorespiratory physiology and those with active hemorrhage within body cavities. These patients cannot be successfully treated for shock until their injuries are treated surgically and until surgical therapy is supplemented by massive transfusions of whole blood. The average stay in a field hospital is usually a week to ten days.

PATIENTS ENDANGERED BY DELAY. Patients whose general condition is good but whose wounds are of such a character that any delay in surgical treatment might have serious consequences are also operated on in field hospitals. Abdominal injuries in which peritonitis might be expected comprise a large number of the cases in this group

ALL OTHER PATIENTS are transported as promptly as possible to evacuation hospitals

6. **Treatment at Evacuation Hospital.** Here the bulk of all initial surgery is done, including débridement of all soft-tissue wounds, application of plaster-of-paris casts, craniotomies, colostomies, amputations, and other procedures which should not be deferred until the general hospital is reached. Depending upon the nature of their wounds, their condition, and military necessities, wounded men are kept in the evacuation hospital from a few hours to several days before being sent to the general hospitals behind the lines It is important that they should not be kept unnecessarily long in such an installation, which otherwise would quickly become overloaded and would lose its function

7. **Treatment at General Hospital.** Here the bulk of all reparative surgery is done, and elective procedures are undertaken, as in civilian life Soft-tissue wounds left open following débridement at forward installations are closed Fractures are reduced, and skeletal traction or other measures are substituted for plaster-of-paris casts. Peripheral nerve injuries are sutured after a sufficient period has elapsed for possible infection of the original wound to subside Colostomies created at forward installations may be closed Decortication procedures for the management of infected or residual hemothorax are undertaken. In short, all but reconstructive procedures are carried out in the general hospital, in which the wounded soldier is kept until he is sufficiently recovered to become a military effective or until he is evacuated to the Zone of the Interior for reconstructive surgery or for separation from the service

GENERAL MANAGEMENT OF BATTLE WOUNDS

At the field and evacuation hospitals, as pointed out, the first phase of the definitive surgery of war wounds begins. The nature and seriousness of the wound are determined. The patient's general condition is reassessed Such additional resuscitative measures as may be necessary are instituted Fluoroscopic and roentgenologic examination is carried out as indicated Finally, the operative management of the wound is undertaken.

It is well to emphasize at this point that resuscitative measures prior to operation, whether they be instituted at the field hospital or delayed until the evacuation hospital is reached, require the transfusion of whole blood. Except in burns and crush-

ing injuries in which plasma alone is lost the shock observed in war wounds is due to the loss of blood which must be replaced by whole blood Useful as plasma is in preparing a wounded man for transportation and supporting him until he reaches a hospital installation it does not stabilize him for operation The maintenance of a blood bank or the procurement of blood from other sources however desirable it might be is not practical forward of the field hospital located close to the clearing station When that point is reached however the use of plasma should be discontinued as a substitute for blood and transfusions of whole blood should be given It might be added that the transfusion of type specific blood is always preferable to the use of type O blood particularly if large amounts must be given under these circumstances the use of universal donor blood is attended with considerable risk if the agglutinin titer is at all high With the use of low titer type O blood this danger is practically eliminated

Debridement. The first essential of the treatment of a war wound is its conversion by debridement into a clean wound Debridement means the removal of all devitalized and damaged tissue of all tissue especially muscle in which the circulation is impaired and of all loose fragments of bone and other foreign bodies Certain criteria are essential for its proper performance a good light proper positioning adequate exposure secured by incisions of ample proportions preferably in the long axis of the extremity placed with due regard for muscle planes a careful unhurried technic the use of fine hemostats and ligatures and anatomic counterincisions for the removal of deep foreign bodies

The performance of debridement up to this point is no different in military practice from the similar practice in civilian surgery In civilian practice however fractures could be reduced peripheral nerve injuries sutured, and the wound safely closed because the patient would be under continuous observation by the same surgeon in the hospital in which he was operated on In military practice this condition cannot be met and the wound is therefore never sutured as a safeguard against the possible development of infection particularly anaerobic infection which cannot thrive in the presence of oxygen The edges of the wound are covered to their depths by a single layer of fine mesh gauze to prevent their agglutination and to permit the escape of serum A voluminous soft tissue dressing is then applied this minimizes the transudation of serum through the raw surfaces of the wound

The last step in the initial management of a battle wound involving soft tissue is the immobilization of the parts by the careful application of well padded splints or plaster of paris casts Plaster of paris casts should always be well padded and must be bivalved as soon as they are applied

Chemotherapy Abundant experience has emphasized that the safest method of preventing infection is by properly performed debridement and non suture of the wound No chemotherapeutic agent takes the place of good initial surgery As has been repeatedly pointed out [1] no agent exists which can sterilize dead devitalized or avascular tissue or prevent the septic decomposition of decontaminated blood clot Neither the local nor the systemic use of such agents prevents the development of wound infection and their use is now limited to two special objects to prevent local infection from becoming invasive and to widen the scope of surgery beyond previous conceptions

Delayed Primary Suture If the initial debridement has been properly performed it is usually possible to close the wound by delayed suture by about the fourth day the time of closure being determined by the gross appearance of the wound and not by bacteriologic studies A wound which looks clean can safely be closed The presence of

pus, color changes, and edema of the wound edges contraindicate closure until infection has cleared up or until devitalized dead tissue has been removed surgically. Infections which are not extensive can be cleared up within two or three days by the application of moist dressings, after which closure can be proceeded with as planned. As Churchill[1] has pointed out, in the Italian Theater of Operations more than 25,000 wounds were managed by employing these principles without loss of limb or other serious consequences and with primary healing after closure in approximately 95 per cent of the cases. These results are of the greatest importance from the standpoint of military surgery because of the shortened period of hospitalization and military ineffectiveness which they imply.

MANAGEMENT OF SPECIAL TYPES OF WOUNDS

The principles of the management of all types of war wounds are the same, regardless of their location and type.[1,3] Certain types of wounds, however, including extensive injuries of the blood vessels, muscles, bones and joints, wounds of the chest, penetrating wounds of the abdomen, and craniocerebral injuries, require a more elaborate scheme of management.[2,4] The table on page 1232 shows the distribution of wounds and the case fatality rate according to anatomic location in World War II.

The preparation for operation of patients with serious injuries is extremely important, and for this purpose chemotherapy, particularly penicillin therapy, has proved of great value. It is begun as promptly as possible and is maintained through the periods of both initial and reparative surgery until all risk of infection is past. This practice has made possible the performance of extensive surgical procedures which otherwise would have been entirely impractical.

The liberal use of whole blood supplements the use of chemotherapy in cases in which procedures of magnitude are contemplated. Extensive reparative surgery places a heavy drain upon the vitality of the patient, particularly if he has a secondary anemia from an initial heavy blood loss. Secondary anemia, in addition, contributes to chronic infection and delays wound healing. Transfusions of whole blood before, during, and after operation are frequently lifesaving.

Other preoperative measures, such as parenteral fluid therapy, oxygen therapy, and constant intestinal decompression, are used as in civilian practice.

Craniocerebral Injuries[2,4]

Because patients with head wounds do not tolerate transportation well immediately after operation, they are given priority in evacuation to field and evacuation hospitals where they can be adequately treated. It has been demonstrated that the postponement of operation for 48 to 72 hours, if necessary, gives better end-results than attempts at earlier treatment under adverse circumstances.

The first principle of therapy is careful débridement of the scalp, with every attempt to conserve as much skin as possible. In compound fractures, loose bone fragments and accessible foreign bodies are removed, the bone defect being enlarged as necessary, though extensive bone flaps are undesirable. Suggestive evidence of the presence of an underlying clot demands opening of the dura and evacuation of the clot. Penetration of the dura and damage to the brain tissue is treated by removal of the traumatized tissue by gentle irrigation and suction. Craniocerebral wounds are closed tightly or are closed around a small drain, but are never packed. Dural defects are repaired by living grafts of fascia or pericranium. Penicillin therapy is an integral part of all craniocerebral operations. Patients with such injuries are carefully observed throughout their course from the neurologic standpoint.

Maxillofacial Wounds[2-4]

The most important consideration in the emergency management of maxillofacial wounds is the conservation of tissue in order to facilitate subsequent reconstructive procedures In contradistinction to the general policy of leaving war wounds open these wounds are always closed if closure can be accomplished without undue tension The regimen of treatment includes (1) reduction and fixation of fractures of the bony foundation structures (2) isolation of the buccal cavity from wounds of the bone and superficial soft parts by suture of the mucous membrane (3) primary closure of the muscles and skin with provision for adequate drainage (4) the application of moist pressure dressings

Generally speaking wounds opening into the buccal or nasopharyngeal cavities and complicated by compound fractures are best handled by approximation of the soft parts by adhesive straps and bandages rather than by primary suture Tracheotomy must be performed without delay if there is obstruction of the airway but the indications must be clear-cut because of the difficulties of caring for a patient with a tracheotomy in a long evacuation line

Thoracic Wounds [5]

The basis of the present management of thoracic injuries is a shift of emphasis from the treatment of pulmonary and pleural complications which are always secondary to a better comprehension of pulmonary physiology and pathology Such wounds present two distinct phases (1) disturbances of cardiorespiratory physiology which develop immediately and must be handled in forward areas and (2) secondary complications most of which can be avoided by proper initial treatment The objective of all therapy is quick and complete re-expansion of the damaged lung

Sucking wounds of the chest require immediate closure which in the early part of World War II was accomplished by immediate suture without adequate debridement The results were most unsatisfactory Within a short time patients developed tension pneumothorax which was sometimes fatal or their wounds became infected and did not heal thus greatly increasing the difficulties of later management and keeping them in the hospital for weeks and months The present procedure is to effect emergency closure by the application of a fitted pad of gauze heavily coated with petroleum jelly and held in position in large wounds by a few sutures a pressure dressing is then applied These patients are given priority in evacuation to a hospital where wound debridement and surgical closure can be done with proper aseptic precautions

Tension pneumothorax is treated by immediate aspiration or by release of air through a needle inserted into the chest Special provisions are made to obviate its recurrence during transportation usually by the use of a flutter valve fitted to a needle or small catheter inserted into the pleural cavity Localized suppuration following injury is treated by adequate dependent closed drainage Extensive collapse of the lung as the result of total empyema is treated by surgical decortication which is also used in massive organizing hemothorax after evacuation of the clot Local and systemic penicillin therapy is an indispensable adjunct to the management of all thoracic injuries and their complications

By the use of these principles both the incidence and the gravity of posttraumatic empyema and of other complications of thoracic injuries have been greatly reduced and soldiers who under former methods of management would have been hospitalized for months and often would have developed intractable sequelae are now being returned to duty within a few weeks

Abdominal Wounds[2,5]

Abdominal wounds although they comprise a relatively small number of all war

wounds, contribute most heavily to the general mortality rate (see accompanying table), chiefly because of shock, hemorrhage, and peritonitis, the last of which develops rapidly in the absence of prompt initial treatment Patients with such injuries are frequently treated at field hospitals and are given priority to evacuation hospitals, where adequate facilities exist for treatment and where relatively prolonged hospitalization is possible.

General surgical principles are followed in the management of abdominal wounds. Almost without exception they are explored, for the obvious reason that otherwise it is not possible to determine whether or not internal injuries are present. Special emphasis is placed upon the procedure of exteriorization in injuries of the large bowel; the damaged segment of intestine is simply and expeditiously exteriorized by drawing it through a separate incision. preferably in the flank. Other injuries are treated according to the indications of the special case. Intensive postoperative therapy, including penicillin, transfusions of whole blood, constant intestinal decompression, and oxygen therapy have contributed greatly to reduction of the mortality by preventing the development of peritonitis and by lessening its gravity when it does occur.

Wounds of Extremities[2-4]

As in all wars, wounds of the extremities compri-ed the largest group of injuries in World War II. Moreover, although deaths from this cause comprised a relatively small proportion of the total deaths, the percentage of partial or total disability is unfortunately high. Wounds affecting only the soft tissues are treated by the principles described for the management of such wounds, with generally good results. But injuries to the major blood vessels may produce loss of life as well as of limb, and injuries to the bones and joints and to the nerves cause many serious disabilities and require protracted hospitalization Finally, the highly devastating weapons used, especially land mines, resulted in extremely destructive and shattering injuries of the extremities and have left no therapeutic choice but prompt amputation in a large number of cases.

Anatomic Distribution of War Wounds, with Mortality

Anatomic Location	Percentage Distribution	Deaths per 100 Injuries Requiring Time Off from Duty
Head	10 3	9 0
Face	8.0	1.0
Neck	2.1	6.0
Upper extremity (total)	26 5	1.0
Bones only	7.3	2 0
Thorax	8 6	8 0
Abdomen (total)	7 7	20 0
Visceral injuries only	2.0	30 0
Pelvis	0.8	8.0
Spinal cord	1 1	12.0
Lower extremity (total)	34.1	3.0
Bones only	6 5	5.0
General and unspecified	0.8	17.0
Total all cases	100 0	5.0

Injuries of Bones and Joints. The closed plaster technic, which represented *a great advance over former methods of* treating war wounds of the bones and joints, is no longer employed, having been displaced by improvements developed through recent experiences

The pathologic changes which occur in compound fractures, as well as the associated symptoms and signs, determine the nature of immediate methods of relief. Immediately after injury there is a temporary phase of paralysis. the limb feels numb and there is usually little or no pain. Soon afterward the irritative phase ensues and the muscles go into spasm, their con-

tractions driving the jagged ends of the bone into the soft tissues and causing additional damage, often to the major vessels and nerves of the extremity Pain, which sets in as the irritative stage comes on is increasingly severe and contributes to the progression of the initial shock Further trauma and contamination are inevitable if the patient is moved before the limb is immobilized

The responsibility of medical units operating in forward echelons is to control hemorrhage, treat shock, apply occlusive dressings, splint the injured limb and evacuate the patient as painlessly and swiftly as possible to a hospital at which he can be treated

When patients with compound fractures are first seen, the obviously sound dictum "Splint them where they lie is at once put into practice, as follows

Shoulder Joint, Clavicle, Scapula A triangular bandage supports the forearm and arm and holds them to the side of the body

Humerus, Elbow, Forearm An arm sling is used and the whole arm is then bandaged to the side of the body with a triangular bandage (Fig 1058) When plaster becomes available at an installation farther to the rear, an appropriate padded cast may be applied, but it must be split before the patient is evacuated

Forearm, Wrist Hand Massively padded basswood boards are applied to the injured parts by adhesive strips or by gauze bandages, which are tied around the splints at three or four different levels as one would tie a bundle of sticks

Spine The patient is not moved until a litter is available He is placed on it in the supine position, with supports under the fracture site, is lifted with the greatest care, to prevent flexion of the spine, is fixed in the position in which he is placed, and is not again moved until he reaches the evacuation or general hospital

Pelvis The pelvic bones are immobilized

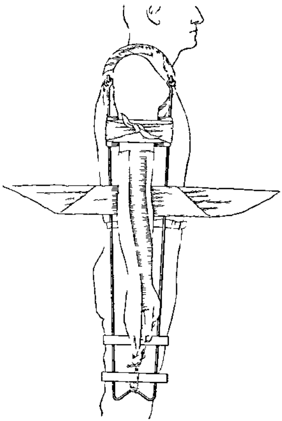


Fig 1058 Hinged traction arm splint for injuries to shoulder joint shaft of humerus elbow joint and upper third of forearm Method of application to upper extremity by two men A making traction while B carries out the following steps Determines site of fracture Removes clothing over shoulder Applies occlusive dressing if fracture is compound Applies strips of adhesive to dorsal and volar surfaces of arm from fracture point or above down to wrist at which level adhesive is doubled back on itself so that it will not adhere to hand Fastens short pieces of light braided cotton rope to lower end of each adhesive strap Passes ring of traction splint around arm until ring rests against chest wall and shoulder girdle Ties ropes from adhesive traction straps to ends of splint Increases traction between ropes with small piece of wood by Spanish windlass principle while 'A' passes similar piece of wood between adhesive straps below fingertips to prevent torsion of adhesive on hand With 'A's help secures arm and forearm to side bars of splint, using three or more triangular bandages Note that hitch about wrist to obtain traction is prohibited (Courtesy Medical Field Manual 8 50, United States Government Printing Office)

by a wide swathe of whatever material is available, and the thighs and legs are fastened together with bandages. Once the patient is placed on a litter he is not moved again until he reaches a semipermanent or permanent installation.

Femur, Knee Joint, Shaft of Tibia. A *traction strap is applied over the shoe by* one corpsman, while another makes traction on the foot (Fig 1059). A hinged half-ring Keller army splint is slid under the leg from the side, and the ring is placed against the tuberosity of the ischium and fixed in this position by the tightening of the strap across the front of the thigh The ring should be at a right angle to the long axis of the splint. The traction strap is secured to the splint with as much tension as pos-

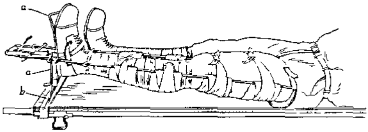


Fig. 1059. Equipment and method of application of traction *fixation splints to major fractures of lower extremity using* army (Keller) hinged half-ring splint. (a) and (a') Interchangeable splint support and footrest; (b) litter bar.

Equipment: Army hinged half-ring splint. Adjustable traction strap Splint rest and foot support—2. Litter bar. Triangular muslin bandages—5 This equipment is included in battalion, regimental, and medical regiment supplies Each and every ambulance transporting patients and answering emergency calls should at all times carry this equipment, and both ambulance driver and orderly should be trained in its application.

Method of Application. Two men, "A" and "B," work together in application of traction fixation splints for transportation, carrying out following procedures

1. "A" grasps and makes traction on foot of patient, while "B" applies traction strap or ankle hitch over shoe
2. While traction is continued by "A," if fracture is compound "B" cuts away clothing about wound and applies an occlusive dressing.
3. While traction is continued by "A," "B" adjusts army hinged half-ring splint (right or left), locking half-ring at a right angle to bars of splint, slides splint in under leg, and secures ring against tuberosity of ischium, tightening anterior strap to hold it there
4. "B" secures traction strap to end of splint and increases traction by Spanish windlass method. "A" lets go his traction on foot.
5. "A" attaches splint support to splint, elevating it from the ground, and assists "B" in securing extremity to side bars of *splint, using four or more triangular muslin bandages.*
6. "A" attaches foot support to splint and ties foot in position against it, using a triangular bandage
7. "A" and "B" place patient on litter and lock splint support in groove of litter bar.

sible, and the tension is increased by one corpsman, on the principle of the Spanish windlass, while another supports the extremity. The extremity is then supported in and fixed to the side bars of the splint by five or more triangular bandages To prevent rotation and fix the ankle the splint rest is attached before attachment of the foot support to which the foot has been secured When the patient is placed on a litter, the splint support is fastened to the litter bar, and the patient is not disturbed

moved to a general hospital Here further surgical revision of the wound is performed as indicated, and anatomic reduction of the fracture is undertaken Simple casts, skeletal traction, the Balkan frame, and the Keller half ring leg splint with Pierson attachment are most often employed, but internal fixation or other methods are used on the proper indications Wounds are closed by suture, and if drainage is necessary it is achieved by a dependent stab wound The after treatment of fractures

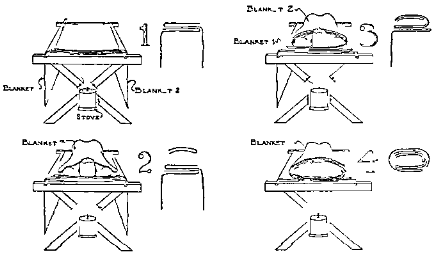


FIG 1060 Diagrammatic illustration of an accepted method of properly blanketing patients for transportation A battle casualty when once properly dressed, splinted, and blanketed at battalion aid station is not removed from his litter until evacuation hospital is reached

again until the evacuation hospital is reached

ANKLE, FOOT After removal of the shoe and sock a right angle splint (Fig 1061) is applied This is made from one or more pieces of ladder wire padded with shell wound dressings So far as is possible the foot is maintained at a right angle to the leg

The splints applied in the forward areas are examined at each halt in the evacuation line and are readjusted as necessary At the field or evacuation hospital surgical debridement of wounds is performed and more adequate plaster-of paris transportation splints are applied The patient is then

does not differ from the practices employed in civilian surgery

In joint injuries wounds of the soft parts are debrided, and damage to bone and cartilage is assessed through incisions large enough to provide good exposure Open arthrotomy is done upon the proper indications, all devitalized cartilage comminuted fragments of bone, and other foreign materials being removed with scrupulous care Impending or early articular infection is usually prevented or aborted by this method The joint space is closed, and penicillin is instilled into it at the conclusion of the operation, but the skin is left unsutured If the joint structure has been

irreparably damaged by the initial injury or by infection, the joint is resected and healing is achieved in a position of maximum function.

Nerve Injuries. From 12 to 15 per cent of all wounds of the extremities are associated with injuries to the major nerve trunks. Primary anastomosis of severed peripheral nerves is usually neither feasible nor desirable In most instances the initial procedure consists only of débridement of the wound and identification of the nerve ends, which are either joined with a sling suture of fine stainless steel or tantalum wire or are anchored with similar suture material to surrounding structures to prevent their retraction. Metal suture material is advisable because it facilitates roentgenologic identification preceding subsequent repair. Patients with nerve injuries are evacuated as promptly as possible to neurosurgical centers in the Zone of the Interior, partly because postoperative care after neurosurgery is protracted and partly because the more promptly surgery is done the less are the degenerative changes in the end-plates of the severed nerves

Vascular Injuries. Injuries to the blood vessels in wounds of the extremities may consist of lacerations, partial or complete severance, thrombosis, or acute spasm. Treatment depends upon the type of injury. End-to-end suture or anastomosis by a tube technic may occasionally be employed in carefully selected cases If ligation is indicated it should be performed well above and well below the area of injury, the damaged segment being excised between these points. Ligation in continuity introduces the risks of secondary hemorrhage, thrombosis, and vasomotor constriction. Localized segmental spasm may follow injury of tissues remote from the vessel or the passage of the traumatizing agent near the vessel In such cases the limb is cold, pale, and lifeless-looking, though there is no evidence of hematoma, laceration, or other vascular damage. Treatment includes

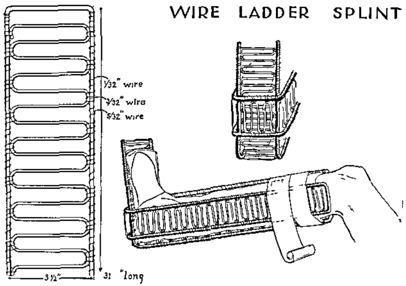


FIG. 1061. Splinting of fractures of ankle and foot for transportation, using wire ladder splint Shoe or boot is removed. An occlusive dressing applied if there is an open wound. Gauze cotton pads are used as padding. Ankle is fixed at a right angle, and splints when padded and applied are held in position by a bias muslin bandage

-ment of the surrounding trauma -issue and novocaine block of the -l sympathetic nerves Sympathetic to induce vasodilation, should be out in all peripheral vascular in- and should be repeated daily accord- the indications Military exigencies -ot permitted any trial of refrigera- a method of extending the period of -y of i chemic tissues by reduction -l metabolism

-utation Although every attempt is -o practice conservatism in wounds of -remities, in a certain proportion of -nly amputation is possible Emer- -mputations in forward echelons are -ed at the lowe t level possible to removal of all devitalized and con- -ed tissue, regardle s of the length stump unnecessary sacrifice of tis- -f course avoided The open circular -ine) method, with severance of suc- layers at the level of retraction of -ng layers, is the procedure of choice -ts in an inverted cone, which is more -e than a stump with a square end -und is always left open Primary introduces the risks of osteomye- -s bacillus infection, and other com- -ns, and usually results in a stump is too short A petrolatum gauze -; is placed over the wound, and skin is applied immediately and con- until healing is complete When -tion is performed in this manner, of the stump at a later date in -nce with prosthetic considerations gives good results

Other Injuries

-es to the eye, to the genito urinary and to other special systems and -e treated in accordance with the -s outlined and without great devi- -om the methods employed in civil -tice Their extended discu sion in -er of this length is obviously not

Burns[24]

While burns account for less than 2 per cent of direct battle casualties their inci- dence among the forces is relatively high, due to the large amounts of gasoline and other inflammable material which must be transported and handled in the line of duty The management of burns was completely revolutionized during World War II Tan- nic acid and other escharotics are no longer used and local treatment is limited to the application of a layer of sterile fine-mesh gauze overlaid by a firm pressure dressing of resilient material such as sterile me- chanics waste This method protects the injured skin prevents further contamina- tion provides against local swelling and loss of fluids gives the patient a high de- gree of comfort and facilitates healing Contractures and excessive scarring are prevented by proper splinting and early skin grafting Systemic therapy is ex- tremely important It consists chiefly of the relief of pain with morphine the preven- tion and control of shock by the liberal u e of plasma and chemotherapeutic meas- ures More lives have been saved and better results have been obtained with this reg- imen than with any method previously employed in the treatment of burns

SPECIAL COMPLICATIONS

Anaerobic infections are rightly dreaded complications of battle wounds because, when once they develop their treatment is difficult and unsatisfactory and the mor- tality is high The incidence of tetanus was reduced almost to zero in World War II, and little space need be devoted to it, since it is no longer a medicomilitary problem of practical importance Gas bacillus infec- tion, however, has not yet been conquered and its importance warrants a somewhat extended di cussion

Tetanus

Although accurate stati tical data are lacking concerning the incidence of tetanus

in military surgery prior to World War I, there is little doubt that it was very high, just as statistics show that it was relatively high among British casualties in the early years of the First World War. In the later years of World War I the incidence was greatly reduced because the use of prophylactic antiserums had become widespread and débridement had been developed and was being uniformly practiced.

In World War II active immunization with tetanus toxoid was universal among American troops, with the result that only three authenticated instances of tetanus occurred in fully immunized soldiers. The advantages of active over passive immunization, particularly from the military standpoint, are well known and need not be repeated here. The procedure of active immunization as now carried out by the United States Medical Department includes:

1. The administration of three doses of tetanus toxoid of 1 cc each at triweekly intervals over a nine-week period.

2. The administration of 1 cc of toxoid one year later as a stimulating ("booster") dose. Regardless of the lapse of time after the original immunization, the immunity afforded by the method described is so effective that no further injections are required in the absence of injury

3. The administration of a stimulating dose of 1 cc. of toxoid if a wound is sustained, the injection being made as soon *as possible after wounding.*

The effectiveness of tetanus toxoid in the prevention of tetanus was completely established in the course of the war. Immunization, however, must be supplemented by proper care of the wound if an injury does occur. The removal by débridement of all contaminated and devitalized tissue and all foreign bodies as soon as possible after the wound is sustained, combined with the routine practice of leaving all wounds open after débridement, has two objectives: to eliminate a medium favorable for the incubation of spores of *Clostridium tetani,* and to hinder (by free exposure to air) the development of infections caused by anaerobic organisms

Tetanus was formerly a common and deadly disease among armed forces If permitted to develop it still carries a high mortality, even in the most experienced hands. As the result of active immunization with tetanus toxoid combined with adequate surgical care of wounds its present incidence is practically nil and its mortality correspondingly nonexistent. Under the circumstances any discussion of therapy would be superfluous

Gas Gangrene[6, 8]

Clostridial myositis (gas-bacillus infection) is an infection of living muscle with anaerobic bacteria of the genus *Clostridium* This group of organisms produces powerful toxins which, by their necrotizing action, favor the local spread of infection, and which later, by their hemolytic action and as the result of wider dissemination, produce a profound, shock-like toxemia. It should be emphasized, however, that it is not possible to distinguish between this toxemia, which is due to clostridial exotoxins, and a toxemia which may be due to the septic decomposition of dead tissue and wound exudates The infection may be limited to a single muscle, but more often whole muscle groups are involved, and swift progression through a whole limb is *not infrequent* Clostridial myositis must be distinguished from anaerobic cellulitis, a circumscribed type of anaerobic infection which involves superficial connective tissue but does not involve muscle

The incidence of gas-bacillus infection among American troops in World War I was 1.7 per cent, and the over-all mortality was between 40 and 50 per cent In the early part of the war, before the importance of early and thorough débridement and of nonsuture of battle wounds was appreciated, both figures were much higher The experience in World War II was sub-

stantially the same and until surgeons in all combat areas learn by bitter experience the importance of these two principles both the incidence and the mortality of gas bacillus infection will remain unjustifiably high Even under the happiest circumstances the mortality is still very substantial MacLennan[6] on the basis of extensive studies in the British Armies in the Middle East wrote in 1943 that very few advances in either prevention or treatment had been made in the last 25 years although during this period antiserums had at least doubled in potency and sulfonamide drugs had been introduced

Bacteriology

The development of anaerobic infections depends upon two factors (1) the presence of anaerobic spore bearing bacilli of the *Clostridium* group (2) the presence of devitalized tissue In the absence of one or the other of these circumstances this particular type of infection does not develop

To date some ten or more species of anaerobic organisms have been identified of which *Cl welchii Cl oedematiens* and *Cl septicum* are probably the most important clinically Usually more than one species is present in an infected wound If only a single species is present it is likely to be *Cl welchii* Concomitant infections with aerobic organisms are common

Clostridial myositis is a bacterial disease but it should not be conceived of in that light It is a definite clinical entity Clostridial organisms are very widely distributed in nature appearing in soil sand and dust of all kinds and in the alimentary tracts of many animals and of man Their distribution in fact is so wide that as MacLennan[6] expresses it their absence from war wounds is a matter for surprise rather than for satisfaction their presence for resignation rather than alarm Their demonstration in a wound does not establish the presence or even the probability of active infection it simply provides the potentialities for it A distinction must be made between simple contamination with these organisms which occurs in perhaps 30 per cent of all wounds and which in most instances goes no farther and active infection with them which occurs in perhaps 1 to 2 per cent of all cases In other words even though the causative organisms are isolated from a wound as they frequently are clostridial myositis does not exist in the absence of clinical symptoms and signs The clinical diagnosis may be confirmed in the laboratory but a laboratory diagnosis of clostridial infection does not establish the presence of the disease Unless this distinction is borne in mind unnecessary radical surgery is likely to be done

Predisposing Causes

In spite of the widespread occurrence of clostridial organisms in war wounds active infections develop only when certain favoring conditions are present These conditions include

1 Tissue whether damaged or undamaged in which impairment of local vascularity has occurred Such impairment may be the direct result of injury to the main arterial blood supply by the traumatizing agent or the result of the noxious effects of bacterial toxins and proteolysis or the result of traumatic or segmental vasospasm or thrombosis It may also occur indirectly as the result of remote interference with the blood supply which not infrequently is caused by injudicious emergency measures including tight bandages and packs tourniquets and plaster of paris casts Plaster of paris casts which are not bivalved immediately upon application or which (if this is not done) are not under constant observation may cause edema of the tissues and subsequent ischemia

2 Wounds in which there has been extensive laceration of muscles compound fractures of the long bones and penetrating wounds of the abdomen and perineum

Necrosis is likely in all injuries of this type, and necrotic tissue furnishes particularly favorable pabulum for the growth of anaerobic organisms.

3. Wounds contaminated with soil, dust, or débris, or wounds in which foreign bodies and fragments of clothing have penetrated deeply into the tissues

4. Wounds in certain areas and involving certain groups of muscles Clostridial infection is particularly likely to develop in wounds of the shoulder the buttocks, and the lower extremities, and in such muscles as the gluteus maximus, the hamstring group, the rectus femoris, the vastus intermedius, and the gastrocnemius. The blood supply of each of these muscles is derived from only one or two sources, and ischemia of the entire muscle results when these sources are cut off. For anatomic reasons wounds of the buttocks are peculiarly susceptible to infection because, no matter how competently they are managed originally, they are constantly recontaminated by the passage of feces In MacLennan's[6] series, 12 of 20 cases of anaerobic infection in this location ended fatally.

5. Improperly débrided wounds which are closed primarily.

6. Wounds complicated by severe hemorrhage and shock, with resultant anemia, or by prolonged exposure and exhaustion, and wounds in which treatment is delayed due to difficulties in evacuation or of other origins.

Prophylaxis

There is no practical method of preventing the access of *Clostridia* to war wounds, and the mortality of established infections, even with the therapeutic methods now available, remains quite high. On the other hand, there are proved methods of preventing the development of infection in the great majority of all cases, and their prompt and correct application is obviously of the greatest importance.

Prophylactic Surgery. Since the basis of the development of anaerobic infections is (1) the presence of necrotic tissue and (2) the presence of tissue in which the local circulation is impaired, if not actually destroyed, the basis of prophylaxis is clearly the wide excision of all tissue which might serve as pabulum for anaerobic microorganisms Prophylactic surgery therefore involves:

1 Sufficient exposure, preferably in the long axis of the limb, to permit ready access to all parts of the wound This frequently requires liberal enlargement of the battle wound

2. Wide removal of all contaminated and devitalized tissue, as well as of tags of bruised fascia, blood clots, detached fragments of bones, and foreign bodies such as bits of clothing and fragments of high-explosive bombs and shells. Because of its peculiar vulnerability to infection, special attention must be given to muscle tissue which has altered in appearance and color and which has lost its ability to contract and bleed Particularly careful excision is also necessary when the wound is in the buttocks or the lower extremities, or when any of the muscles especially susceptible to anaerobic infections has been damaged If the wound is jagged, it is important that all pockets and irregular spaces be cleaned out and adequately drained The use of x-ray films at operation is helpful in insuring that all opaque foreign bodies have been removed

3. Strict limitation of the excision to damaged and doubtful tissue. The sacrifice of healthy tissue and of unnecessary amounts of skin should be avoided, and the integrity of major blood vessels and of nerves should be preserved A properly performed débridement leaves a clean, healthy-looking wound, in which drainage is adequate.

4. Nonsuture of the wound The number of instances in which primary suture is a safe procedure is limited, and it is a practical impossibility to identify such cases at

operation Nonsuture of the wound is therefore the proper routine

5 DRESSING of the wound with petrolatum gauze or with dry fine mesh gauze followed by immobilization by splinting Tight packing and the application of tight bandages which are likely to impair the circulation and which favor tissue necrosis are to be avoided Splinting of the parts is best done by any method other than the application of a plaster of paris cast If for any reason such a cast must be applied it should be bivalved immediately after its application Local chemotherapy should be omitted While there is some difference of opinion on this point the consensus is that neither local nor systemic sulfonamide therapy has fulfilled its early promise in the prophylaxis of gas gangrene

Uniformly successful results from the prophylactic regimen outlined above are possible only when the patient is seen with reasonable promptness within several hours at the most If he is seen later the procedure depends upon the circumstances If excision seems unwise but actual infection has not yet developed adequate drainage may be provided by appropriate incisions If infection has developed the regimen to be outlined for established anaerobic infections must be instituted without delay

Postoperative Care The patient is evacuated as soon as possible after operation to an installation with facilities for adequate postoperative observation and should remain in it until all risk of the development of anaerobic infection is past This precaution is especially necessary if the main arterial blood supply of a part has been injured or if the wound is such that the development of anaerobic infection seems likely It is a wise precaution to note on the medical record which accompanies the patient the necessity for careful observation

In cases in which traumatic or segmental vasospasm seems a possibility, repeated novocaine block of the regional sympathetics is carried out Otherwise only routine postoperative measures are employed Gas gangrene antitoxin is not given Its prophylactic value remains to be established and its use is not recommended at this time

Clinical Picture and Diagnostic Considerations

The length of the incubation period in anaerobic infections varies depending upon the nature and virulence of the affecting organisms the degree of damage to the tissues the amount of blood lost the presence of shock fatigue or other factors which lead to a diminution of resistance and finally the adequacy of prophylactic surgery and the time in relation to the initial wound at which it was performed Infection has been reported as early as three or four hours and as late as four or five days after the wounding but in the majority of cases it occurs within the first two or three days When once it does occur the onset is acute progression is rapid and the patient may be in extremis within a few hours Since the value of curative therapy is limited at best and since its results depend chiefly upon the promptness with which it is instituted the importance of constant observation of the patient and of prompt diagnosis of impending infection is obvious

Symptomatology Generally speaking the first symptom of the onset of clostridial myositis is sudden acute pain in the wound which as MacLennan[6] has pointed out is sometimes so abrupt as to suggest a vascular catastrophe Once established the pain remains constant and does not disappear until it is relieved by surgery or until massive gangrene has occurred when as a rule the patient is moribund Pain of this character and with such an onset is of great diagnostic importance As MacLennan[6] observes even a wounded man if lying normally in bed would not suffer in

this manner unless something were very *wrong indeed.*

Accompanying the pain, and also of great diagnostic significance, is a steadily rising pulse rate. The pulse volume at first is good, and only later does it deteriorate The accelerated pulse may or may not be accompanied by hyperpyrexia When toxemia is fully developed the temperature is likely to be subnormal. The rising pulse rate, combined with the shock-like state characteristic of advancing toxemia, may suggest traumatic or hemorrhagic shock, but the differentiation is not difficult Except when the incubation period is unusually brief the time interval is too long to permit a diagnosis of traumatic shock, and hemorrhagic shock is readily differentiated by serial blood-pressure observations In early stages the blood pressure is likely to be normal or slightly elevated, and even in late stages it is not lowered to the same degree as in ordinary shock

In the occasional case vomiting is sometimes the first suspicious sign. It frequently becomes marked as toxemia progresses

Other signs of toxemia develop rapidly The facies becomes ashy in most cases, though occasionally it is flushed. In some instances jaundice is a terminal phenomenon. The skin is frequently covered with sweat. The patient looks anxious and apprehensive. Mental changes are various In some instances he is bright-eyed and extremely alert, in others he presents a picture of complete apathy. In still other instances there may be low, muttering delirium or, occasionally, acute mania

The clinical picture described is the classic picture and refers chiefly to infections with *Clostridium welchii,* which are the most frequent type In infections with *Cl. oedematiens* a sense of weight may precede the development of acute pain in the injured part. MacLennan,[6] who first described this symptom, did not observe it constantly, but obviously it is of great significance when it is present. The condition of the patient becomes poor at a very early stage, *the toxemia being entirely out of* proportion to the local findings The pulse volume is poor and the blood pressure depressed. The mental changes described for infections with *Cl welchii* are usually less striking in *Cl oedematiens* infections, though they may be present In this variety of the disease hemoconcentration is likely to be present because of the local "wet" infection

Local Findings. A description of the local findings in clostridial myositis properly begins with the statement that the presence of gas has been emphasized far too much, both clinically and from the diagnostic standpoint Gas is not constantly present Although it is occasionally (usually accidentally) demonstrated by x-ray in early cases, as a rule it appears later. It may never be apparent because it is masked by associated edema and gangrene. In massive gangrene a tympanitic note is nearly always present on light percussion over the involved areas, and even in localized cases, if the muscles are superficial, careful examination will sometimes reveal it It is well to remember also that even if gas is present and demonstrable, the area of demonstration does not necessarily correspond with the area of infection in the deeper tissues The significance of this observation from the standpoint of surgical therapy is clear

Another point to be emphasized is that clostridial myositis is not necessarily associated with a characteristic odor, which has been variously described as sweetish, like rotten meat, and like acetylene gas in low concentration While this odor may be present in many cases, the wound may emit no odor at all, and fatal delay in the institution of treatment may ensue if diagnosis is postponed until the appearance of the so-called characteristic odor

The appearance of the wound depends upon the variety of infecting organism and upon the degree of exposure to air. Changes

are never so extensive in an open wound exposed to air as in a totally or partially closed wound The full extent of the pathologic changes cannot be properly comprehended until the wound is examined in the operating room under a good light and after proper exposure Such an examination should be carried out without delay in all cases in which the diagnosis of clostridial infection cannot be promptly and positively excluded

In the earlier stages of *Clostridium welchii* infections the muscles are somewhat swollen are paler than normal and lack their normal luster Later they become a characteristic slate blue color Edema is not marked and is more striking in the subcutaneous tissue than in muscle tissue The muscles themselves are pulpy and friable and do not bleed on incision or contract on stimulation The surface of the wound is usually dry though a small amount of thin frequently blood stained exudate may escape from the edges on gentle pressure Gas production is marked but the discharge does not become profuse as in the *Cl oedematiens* variety of infection

Edema is the outstanding local characteristic of infection with *Cl oedematiens* It involves all the tissues of the wound and is not usually hemorrhagic The muscles which are greatly swollen at first are pale and abnormally firm Later they become brick red or dark purplish red and still later they have a typically gangrenous appearance At this stage they are slimy and friable and eventually they are pultaceous The line of demarcation between involved and normal muscles is particularly clear cut when the infection is confined to superficial muscles

In both varieties of infection the disease progresses longitudinally up and down the affected muscle or muscle group from the site of the original lesion There is little tendency to spread from muscle group to muscle group

The skin changes in both varieties of infection are variable and are not necessarily related to the extent of the underlying infection Apparently healthy skin may overlie seriously infected tissue and vice versa In the early stages of the infection the only significant skin change is blanching about the wound on pressure Changes are seldom marked in *Cl welchii* infections if the gas bacillus infection is associated with streptococcal infections a coppery discoloration is sometimes observed this discoloration may also appear terminally in uncomplicated infection Skin changes in *Cl oedematiens* infections include edema tenseness a dirty brown discoloration marbling of the surface from stasis in subcutaneous veins and occasionally areas of ischemic gangrene

Differential Diagnosis from Anaerobic Cellulitis Anaerobic cellulitis is a circumscribed type of anaerobic infection which affects superficial connective tissue rather than muscle even in areas tympanitic with gas the muscles retain their normal color and contractility Edema of traumatic origin may be present but is not characteristic of the infection The incubation period is longer than in clostridial myositis the onset is much more gradual and systemic disturbances are minimal at least in comparison with the profound changes observed in clostridial myositis

The distinction between the two conditions is extremely important In anaerobic cellulitis free incision with excision of locally infected tissue is usually adequate In clostridial myositis radical surgery which sometimes includes amputation is necessary If the differential diagnosis is not made unnecessary surgery will obviously be done in many cases

Therapy

The therapy of established gas bacillus infection falls into two parts (1) control of the infection (2) combating of toxemia These objectives are accomplished by a combination of surgery, antitoxin, chemo

therapy, and supportive measures, which must be instituted without delay. A patient whose general condition makes him suitable for immediate surgery should be operated on at once, without pause for any but routine preparation. A patient in poor condition should receive from 500 to 1,000 cc of whole blood and should be given antitoxin while the transfusion is running, but there should be no further delay, for he is not likely ever to be in better condition. Many writers have pointed out that in clostridial myositis the swift progression of the infection always outstrips attempts at rehabilitation.

The surgical procedure consists of the wide excision of all involved tissue, particular care being taken that the excision is continued into tissue that is indubitably healthy. The extent of the procedure depends upon the degree of the involvement Occasionally the excision of a single muscle is adequate More often the excision of an entire muscle group or of more than one group is required In extreme cases only amputation is adequate, and care must be taken that it be performed well beyond the upper limits of the infected tissue. If radical surgery is impossible because of the site of the infection or the condition of the patient, free incision of the muscle sheaths and muscles will relieve tension, but it should be emphasized that this is a procedure of expediency, not of choice. In such cases, if a limb is involved, the application of a tight tourniquet proximal to the upper limit of infection has been found helpful in establishing a sort of physiologic amputation.

Because thrombophlebitis and pulmonary embolism are acknowledged hazards in clostridial infections, it may be necessary, when amputation is performed or later during convalescence, to aspirate thrombi from veins or to perform venous ligation These procedures should not be performed routinely but only upon the proper indications

Penicillin may be instilled into serous cavities or into major joints to complement initial or subsequent surgical management but with this exception the local use of chemotherapeutic agents is not advised

It cannot be too strongly emphasized that surgery, with the establishment of adequate drainage, is the basis of the therapy of clostridial myositis Every other measure is adjuvant to it, and no other measure, however intensively carried out, can offset the risk of residual dead spaces or improper drainage

Measures adjuvant to surgery include

1. Administration of Trivalent Gas-gangrene Antitoxin This is done in an effort to neutralize toxins The value of antitoxin is still to be established, but until it is proved to be of no value it is the part of wisdom to employ it It is preferably given intravenously after the proper precautions have been taken against anaphylactic shock. A minimum dose of 3 ampules (each ampule contains 10,000 units of *Cl welchii* and of *Cl septicum* and 1,500 units of *Cl oedematiens*) is repeated hourly at the discretion of the medical officer until six doses have been given

2 Administration of Penicillin Before operation, or in the course of the procedure, the patient is given an initial intramuscular dose of 30,000 units Three hours later a slow intravenous drip is begun, at the rate of 5,000 to 6,000 units per hour, and is continued for 24 to 48 hours If administration by this route is not feasible, 15,000 units is given intramuscularly at three-hour intervals The aim is to give from 200,000 to 400,000 units daily, and to continue the administration for three to five days after all clinical symptoms and signs of infection have disappeared Penicillin, in the light of present knowledge, has no curative effect, but it is useful in limiting further invasion of healthy tissue Since this drug has become generally available, sulfonamide therapy in clostridial infections is no longer employed There is no

reason to employ it in addition to penicillin for there is no sound evidence of synergism between the two drugs and the use of sulfonamides simply introduces the risk of toxic reactions

3 LIBERAL USE OF WHOLE BLOOD In clostridial infections there is rapid and extensive destruction of erythrocytes and their replacement plays a large part in the patient s survival Plasma does not fill this need and should be reserved for the correction of persistent hemoconcentration in the occasional selected case

4 MAINTENANCE OF A PROPER FLUID BALANCE Such a balance is maintained by the free oral intake of fluids if vomiting does not prevent and by the use of parenteral fluids as necessary The maintenance of the fluid equilibrium is important for anuria is a fairly frequent complication of the di ease though the exact mechanism of its development is not known It is well known that kidney tissue is very vulnerable to anoxia secondary to protracted circulatory failure [8]

5 CONSTANT INTESTINAL DECOMPRESSION This is done as necessary to combat abdominal distention and gastric dilatation

Part III

THE MEDICAL ASPECTS OF GAS WARFARE[9]

By MAJOR GENERAL NORMAN T KIRK

Because gas was used in World War I it was necessary to provide against its use in the Second World War but toxic gases were not employed in the more recent conflict This section is included in the chapter on military medicine however for the sake of completeness and to present in brief outline the essential medical considerations of this variety of warfare No attempt will be made to review in detail the great amount of material available on this subject

CLASSIFICATION OF GASES

For medical purposes the most useful of the various systems of classification proposed for chemical warfare agents is one which segregates them according to primary physiologic action It should be pointed out that the classification which follows while satisfactory from this standpoint makes no allowance for the secondary effects of which many of these agents are capable and does not include either the incendiaries (white phosphorus magnesium and its alloys thermite and oils) or the screening smokes (HC mixture titanium tetrachloride or sulfur trioxidechlorsulfonic acid solution) which also must be combated

Physiologic Action	*Gases*
Vesicants (blister gases)	Mustard Nitrogen mustard Lewisite Ethyldichlorarsine Phenyldichlorarsine
Lung irritants (choking gases)	Phosgene Chlorpicrin Chlorine
Sternutators (vomiting gases)	Diphenylaminechlorarsine Diphenylchlorarsine Diphenylcyanarsine

Physiologic Action	*Gases*
Systemic poisons (blood and nerve poisons)	Hydrocyanic acid Cyanogen chloride Arsine
Lacrimators (tear gases)	Chloracetophenone Chloracetophenone solutions Bromobenzylcyanide

Vesicants

Vesicants as a group act primarily on the eyes and skin, though when inhaled they injure the respiratory tract and when absorbed they cause systemic poisoning.

Mustard. The eyes are more vulnerable to mustard than is any other part of the body. There are no immediate symptoms following exposure; the latent period, depending upon the degree of exposure, ranges from one or two hours to twelve hours. The resulting lesions vary from mild conjunctivitis to severe injuries of the cornea with opacification, ulceration, and vascularization.

No decontamination procedure is of any value following exposure of the eyes to mustard vapor only. When the contamination is by liquid mustard, immediate attention is necessary, since first aid procedures more than two minutes after exposure are of little value BAL ointment is squeezed directly into the lower conjunctival sac, and this application is followed by pain and blepharospasm, though previous symptoms have been lacking. The eye is massaged for one minute and is then irrigated for one-half minute to two minutes. The irrigation will usually relieve or completely stop the pain caused by application of the ointment

Mild conjunctivitis is treated symptomatically. Three per cent sodium sulamyd solution (two drops) is instilled every four to eight hours to prevent infection. In more severe cases, with edema of the lids, photophobia, blepharospasm, and other obstructions of vision, pain is likely to be persistent and must be controlled by morphine or other systemic sedation. Mydriasis is effected by the use of atropine solution (1 per cent). Infection is prevented by the instillation of a few drops of 3 to 10 per cent solution of sodium sulamyd every four hours, or by the use of penicillin (1,000 units per 100 cc) or of sulfathiazole ophthalmic ointment. Secretions are removed by gentle irrigations with isotonic saline solution Bandages are not used, and care is taken that the lids do not adhere to each other Infections are treated by the instillation of 10 per cent sodium sulamyd every two hours, or by the local use of penicillin or sulfathiazole ophthalmic ointment every four hours

No immediate symptoms follow the exposure of the skin to mustard vapor or liquid At the end of a latent period of one to twelve hours erythema appears, with itching and some burning Erythema is followed by vesication after all but mild exposures Liquid mustard on the skin must be decontaminated promptly The excess liquid is blotted off, M-5 protective ointment is applied freely, the excess is removed, and more ointment is applied and is allowed to remain until it can be washed off with soap and water Erythema is treated symptomatically. Blistered and denuded areas are treated by the application of sterile petrolatum, which is covered by sterile pressure dressings A sterile technic must be employed, and frequent changings of dressings are avoided Specific antibacterial therapy is employed according to the indications. Penicillin, which is the drug of choice, is given intramuscularly in doses of 25,000 units every three hours as long as indicated.

Symptoms following the inhalation of

mustard vapor come on slowly They begin with hoarseness and possibly aphonia and progress to cough fever and dyspnea The lesions *range from mild hyperemia of the* laryngeal and tracheobronchial mucosa to congestion of the pulmonary parenchyma with mild patchy edema emphysema and focal atelectasis Bronchopneumonia is a frequent complication Cough and irritation are treated symptomatically and laryngitis and bronchitis are treated with steam inhalations When clinical evidence of severe respiratory tract injury exists penicillin is given prophylactically to prevent bronchopneumonia If pneumonia develops it is treated exactly as it would be under other circumstances

Absorption of mustard through the skin or the ingestion of mustard contaminated food or water may cause severe gastro intestinal disturbances such as pain nausea and vomiting and diarrhea The patient may develop fever and is often prostrated When the quantity of mustard absorbed approaches the lethal dose the hematopoietic tissue may be damaged as evidenced by leukopenia and thrombocytopenia in the peripheral blood Discomfort and restlessness are relieved by barbiturates Morphine may be necessary to reduce gastro intestinal activity Infusions are employed according to the indications to maintain the fluid and electrolyte balance

Nitrogen Mustard The eyes are affected more quickly by nitrogen mustards than by mustard though not as quickly as by lewisite The lesions are in general similar to those caused by mustard but the symptoms may be more severe and local necrosis of the cornea may terminate in rupture of the globe Decontamination and treatment are the same as described for mustard

The decontamination of liquid nitrogen mustard on the skin the treatment of skin lesions and the management of lesions of the respiratory tract are the same as for mustard

The most pronounced effects of the absorption of nitrogen mustards through the skin or the respiratory or gastro intestinal tracts are on the hematopoietic tissue and *lymphoid tissue Degenerative changes in* the bone marrow may be followed by involution of the thymus spleen and lymph nodes resulting in lymphopenia granulocytopenia thrombocytopenia and anemia Vomiting and diarrhea are frequent symptoms Treatment consists of transfusions of whole blood with other parenteral fluids according to the indications

Lewisite Liquid lewisite is particularly damaging to the eyes Pain and blepharospasm immediately follow exposure and there is immediate searing of the cornea Edema follows promptly and the eye is closed within an hour The degree of corneal injury depends upon the degree of exposure Healing may occur without permanent defects but the more severe exposures may terminate in pannus formation or massive necrosis Decontamination and treatment are the same as for mustard In contrast to its effect in exposure to mustard however BAL ointment will immediately relieve the pain and blepharospasm caused by lewisite and if it is used within one minute of exposure healing usually occurs without permanent damage If it is not used for ten minutes healing will occur but there will be some residual defects After 30 minutes it is of no value

The contact of liquid lewisite with the skin produces within a few seconds a stinging pain which quickly increases in severity Erythema appears in about 30 minutes and vesication in about 12 hours The blisters in contrast to blisters caused by mustard are painful The blister fluid is nontoxic and nonvesicant The tissue damage caused by lewisite is in general more severe than that caused by mustard

Ideally lewisite is decontaminated by BAL ointment which is spread on the skin in a thin film rubbed in and allowed to remain for a minimum of five minutes By this method of application the lewisite

which has been absorbed is neutralized, as well as the lewisite on the skin In practice, since M-5 ointment is a good decontaminant for lewisite, though not as effective as BAL ointment. the soldier is taught to use the former for all liquid contaminations of the skin, the reason being that in the confusion of battle it would be difficult for him to distinguish between the blister gases and to apply the appropriate decontaminating ointment Treatment of the various phases of lewisite burns is the same as the treatment outlined for mustard burns

Inhaled lewisite vapor is extremely irritating to the respiratory passages. The lesions are similar to those caused by mustard. Therapy combines the treatment outlined for mustard injuries of the respiratory tract and the treatment to be described for systemic arsenical poisoning.

Systemic poisoning with lewisite results from the absorption of liquid lewisite from the skin or of lewisite vapor from the respiratory tract. Pathologic changes include the loss of fluid from damaged capillaries, which may be so severe as to cause hemoconcentration, shock, and death, hemolysis, focal necrosis of the liver as the result of oxidized products of lewisite, and pulmonary edema, which may follow either direct inhalation of the vapor or absorption of the liquid agent through the skin

Indications for the treatment of systemic lewisite poisoning include

1. Any evidence of pulmonary edema, such as a cough with dyspnea and frothy sputum,

2. Any skin burn the size of the hand or larger, if decontamination has not been effected within 15 minutes of exposure,

3. Skin contamination of 5 per cent of the body surface if evidence of skin damage appeared within 30 minutes,

4. Blisters which are the size of the hand or larger.

When lewisite has been absorbed through the skin, BAL ointment is rubbed into the affected areas and is not removed. An appropriate dose of BAL in oil (10 per cent) is given intramuscularly into the buttocks, the dosage being adjusted to the estimated body weight (125 pounds, 2 5 cc 150 pounds, 3 0 cc , 175 pounds, 3 5 cc 200 pounds, 4 0 cc). The original dose is repeated every four hours until four doses have been given In severe cases the interval between the first two doses is shortened to two hours, and a single daily dose in half the amount of the original dose is given for three or four days after the specified four doses have been given

A wide variety of symptoms and signs may occur 15 to 30 minutes after the injection of BAL in oil The most serious is a transient rise in blood pressure Reactions may last 30 minutes, but unless they are prolonged or unduly severe they do not contraindicate the administration of a full course of treatment.

Ethyldichlorarsine and Phenyldichlorarsine. The pathology and symptomatology caused by these agents, as well as the decontamination and treatment, are similar to those already described for lewisite

Lung Irritants

Of the important lung irritants, phosgene produces its primary effects on the lung parenchyma, while chlorpicrin and chlorine are more likely to injure the trachea and the bronchi.

Phosgene. When phosgene is inhaled, initial damage to the capillaries of the lung parenchyma is followed by loss of fluid from the capillaries and by early massive pulmonary edema. Loss of plasma into the alveoli results in hemoconcentration Pulmonary edema reaches its maximum 12 to 14 hours after exposure, and gaseous exchange in the lung is inhibited In fatal cases death from anoxemia usually occurs within the first 24 to 48 hours In nonfatal cases edema begins to subside at the end of 48 hours. Secondary bronchopneumonia may develop three to five days after exposure To prevent its development specific anti-

bacterial therapy preferably penicillin may be given prophylactically when edema begins to subside

The severity of the early symptoms of phosgene poisoning which include coughing choking or vomiting is not a prognostic yardstick In some cases a latent period of 2 to 24 hours is followed by signs of pulmonary edema of which cyanosis is the most ominous The condition may progress steadily the patient eventually passing into a shock like state A person exposed to phosgene may continue with his duties for some time before signs and symptoms of respiratory distress appear When they occur he must at once be put at complete rest kept comfortably warm and given oxygen in as high a concentration as possible If he continues in distress morphine may be given guardedly in small doses When cough is the most prominent symptom codeine is used

A number of methods have proved useless or even harmful in the treatment of phosgene poisoning these include atropine plasma parenteral fluid and cardiac and respiratory stimulants such as adrenalin ephedrine benzedrine coramine metrazol and alcohol Venesection has not proved beneficial and is always definitely harmful particularly if it is practiced during the shock like state

Chlorpicrin The effects of this agent are essentially the same as those of phosgene and the treatment is the same It is however quite irritating to the eyes and is more destructive than phosgene to the bronchiolar epithelium Symptomatic treatment is sufficient if the injury to the eyes is mild

Chlorine The immediate symptoms of chlorine poisoning which include burning in the throat coughing and a sense of suffocation are the result of injury to the upper respiratory tract Chlorine however is extremely irritating to the entire respiratory tract The treatment is the same as for phosgene poisoning

Sternutators

Sternutators are dispersed by heat as smokes The group includes diphenylamine chlorarsine (adamsite) diphenylchlorarsine and diphenylcyanarsine The medical aspects of all three agents are similar

These poisons irritate the nose sinuses throat and eyes The symptoms include pain and a feeling of fullness in the nose headache a sensation of burning in the throat tightness in the chest very severe coughing and sneezing lacrimation frequently nausea and vomiting sometimes mental depression

Except when actually vomiting the patient should wear a gas mask during exposure to these agents The inhalation of chloroform at intervals brings considerable relief Prompt recovery is the rule in all cases

Systemic Poisons

The primary effects of this group of poisons are produced after they are absorbed into the body

Hydrocyanic Acid This agent produces its effects by combination with an enzyme essential for proper oxidation within the tissues The respiratory center is particularly susceptible In high concentrations there is an increased depth of respiration within a few seconds followed by convulsions in 20 to 30 seconds and cessation of respiration within 60 seconds The heart beats for several minutes longer

As soon as the gas mask is applied two ampules of amyl nitrite are crushed and placed beneath the facepiece this procedure being repeated every three to four minutes until eight ampules have been given The nitrites immediately form methemoglobin which competes with the enzyme in taking up the cyanide When it is available 10 cc of 1 per cent sodium nitrite should be injected intravenously over a period of one minute every 10 minutes until a total of 50 cc has been given each injection of nitrite is alternated with the intravenous

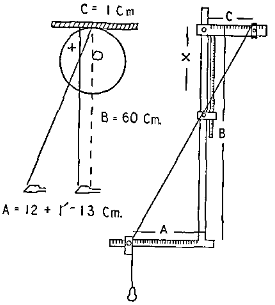


FIG. 1062. (*Left*) Localization of foreign bodies by triangularization

A = tube shift distance plus distance between center of shadows on film (base of first triangle) 12 cm. + 1 cm. = 13 cm.
B = target—film distance (altitude of first triangle) 60 cm.
C = distance between shadows on film (base of second triangle) 1 cm.
X = depth of foreign body from film (altitude of second triangle)

$$A : B = C : X$$
$$13 : 60 = 1 : X$$
$$X = 4\ 6 \text{ cm.}$$

FIG. 1063. (*Right*) Mechanical device for depth estimation in similar right triangles.

A = distance of tube shift
B = distance of fluoroscopic screen or film from tube target.
C = distance of movement of foreign body on fluoroscopic screen or film in the two exposures.
X = altitude of the second right triangle, and is distance of foreign body from film or screen

Deducting distance of film or screen from skin gives depth from skin of foreign body.

the exposures in several different planes to demonstrate a shadow by the thickest plane of the foreign body.

LOCALIZATION BY BIPLANE FLUOROSCOPY AT RIGHT ANGLES

If the foreign body is visible fluoroscopically the point of entrance and exit of the central ray through the body may be marked on the upper and lower skin surfaces; then, without changing the position of the part, similar entrance and exit marks are made on the lateral skin surfaces at a 90° angle to the central ray beam of the first procedure. The foreign body must then lie at the point of intersection of the right-angle beams.

REMOVAL UNDER DIRECT GUIDANCE OF FLUOROSCOPY DURING TIME OF OPERATION

This is one of the most practical and rapid methods With the modern shockproof equipment operated behind a sterile sheet and a hand fluoroscope enclosed partially in a sterile covering, it is comparatively easy to obtain a view in the lateral plane and to maintain a sterile field. To obtain the view from top to bottom of the part, the patient is operated upon on the regular fluoroscopic table and the fluoroscopic screen frame is covered with a sterile cover, leaving a six-inch square on the top of the screen uncovered for visibility Directions may then be given intermittently and the screen moved out of the field during the interval If the foreign body is metallic and 1 cm or more in size, the operator, even without eyes accommodated, can usually see the shadow and its relation to his instrument.

Needless to say, this method should be used only by one having full knowledge of the effects of x-rays on body tissues, for an excessive amount of radiation is certain to cause deleterious effects on any tissues in its path in either patient or operator

NEAREST-POINT METHOD

The point on the skin nearest the foreign body may be determined for many bodies

in the extremities, neck, and superficial structure during fluoroscopic examination A metal tipped palpating rod is used to make pressure and move the tissue in the region of the foreign body The point on the skin where the maximum movement of the body is obtained is its closest point to the skin By viewing this area in profile with the palpating metal tip on the skin point, the depth of the body may be very accurately determined

DEPTH DETERMINATION BY COMPUTATION FROM RIGHT TRIANGLES

For practical work this may be carried out either by film or by fluoroscopic methods, either of which will determine the depth of a foreign body from the skin surface within a fraction of a centimeter

The principle of the method is dependent upon the fact that in similar right triangles the ratio of the base to the altitude of one is equal to the ratio of the base to the altitude of any other similar right triangle

The base and altitude of one right triangle is known, i e the altitude is the distance from the tube target to the film or screen, and the base is the distance of the tube shift plus the distance between the shadows of the foreign body of the film or screen from the two exposures The base of the other similar right triangle is the distance between the shadows of the foreign body as measured on the film or screen The altitude of this second similar right triangle is the distance of the foreign body from the film or screen (radiographic or fluoroscopic method) and represents the distance of the foreign body from the skin surface if it is in contact with film or screen If not in contact, of course, this distance of separation must be subtracted from the distance determined for the altitude to obtain depth from skin surface

The accuracy of the method (Fig 1062) depends on

1 The exact centering of the foreign body shadow with the smallest diaphragm opening by which it is visible on the screen (mark the skin surface at this point)
2 Centering of the tube exactly over this point,
3 Shifting the tube a definite distance (a 12 cm shift is practical),
4 Keeping the film or screen stationary during both exposures

Ingenious methods of rapid calculation have been worked out by the use of arbitrary measurements to represent centimeters, and there are also ingenious mechanical devices to find quickly the unknown altitude of the second triangle A device described in the U S Army X ray Manual (first edition)[10] is both accurate and simple (Fig 1063)

Where a large number of cases are to be handled it is necessary to organize teams for this work, and obviously both the x ray and surgical teams should be familiar with the uniform method used

Reid and Black[11] have prepared an excellent bibliography on the subject and have described a fluoroscopic method recommended for use in the U S Army

The important point for centering all fluoroscopic work is to use the smallest diaphragm by which the foreign body is visible on the screen

A suitable ink for marking the skin is the Finzi ink

Pyrogallic acid	1
Acetone	10
Liquid chloride of iron	4
Wood alcohol q s	20

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Index

This index covers both Volumes I and II Light face numerals (123) refer to Volume I, bold face numerals (**123**) to Volume II Numerals in roman type (123 **123**) refer to text Italic numerals (*123* ***123***) indicate illustrations and legends on the page reference given